# BIOLOGIA

Vol. 1 JUNE, 1955 No. 1

## Pezizales of West Pakistan

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The present paper deals with the operculate cup-fungi collected in the hills during the last seven years. In all 50 species are reported here, two of which are new to science.

The author has followed Boudier (1907), Nannfeldt (1932) and Seaver (1948) in restricting the term Pezizales to include only the operculate Discomycetes (Pezizaceae and Helvellaceae). This is in sharp contrast with the classification adopted by Gaumann & Dodge (1928), who use the Pezizales synonymously with the Discomycetes, or by Bessey (1950), who includes both operculate and inoperculate forms in the order Pezizales.

The only records of Pezizales from West Pakistan are those by Mahju (1933) and Ginai (1936), who came across a few species of this group in the course of their studies on coprophilous fungi. Mahju recorded only two species of Pezizales, viz., *Ascobolus viridis* Curr. and *Lasiobolus hirtellus* Karst., as occurring on the dung of different mammals. As regards the species listed as *Ascobolus viridis*, it may be mentioned that it has undoubtedly been identified wrongly. Mahju describes it as having spores measuring 19-22 x 9-11 μ, whereas *A. viridis* Curr. is humicolous and has spores measuring 25-32 x 11.5-13 μ. From his description it appears that the species in question is *Ascobolus stercorarius*. Similarly Mahju's description of *Lasiobolus hirtellus* differs markedly from the original description by Karsten, especially in the size of the spores. It is not possible to know which species Mahju had under observation.

Ginai listed the following species of Pezizales as being coprophilous :

1. *Peziza subcupularis* Rehm

2. *Humaria carpophila* Bizz.
3. *Humaria orthotricha* B. & C.
4. *Saccobolus versicolor* Karst.
5. *Ascobolus minutus* Boud.
6. *Rhyparobius crustaceus* Fckl.

As regards the first of the above mentioned species, the size of the fruit body (2-5 mm.) recorded by Ginai shows beyond doubt that it is no species of *Peziza*. *Peziza subcupularis* Rehm belongs to the section " majusculae " of Saccardo, is arenicolous and does not grow on dung. *Humaria carpophila* Bizz. again, is not coprophilous but occurs on immature rotting fruits of *Quercus* and *Tilia americana* in Italy. *Humaria orthotricha* B. & C. occurs on soil and bark among mosses, esp. *Orthotricha* in America and is not coprophilous. *Saccobolus versicolor* Karst. has been recorded only from Finland. Ginai's description of the species does not agree with the original and he has no doubt misdetermined some other species. *Ascobolus minutus*, as described by Ginai differs in colour and size of the asci and ascospores from the original description of this species.

It is a matter of great regret that these authors did not preserve any material for future checking so that there is no means of knowing what species they had under observation. With the exception of *Rhyparobius crustaceus* Fckl. all other records should therefore be deleted from the list of the Pezizales from this area.

Recently, on the basis of a few collections by the present author, Cash (1948) has reported the following 4 species from West Pakistan:

1. *Humaria ahmadii*
2. *Humarina plumbeoatra*
3. *Humarina umbrina*
4. *Humarina zizyphi.*

I am gratefully indebted to Miss Edith K. Cash, Beltsville, Maryland, for the identification of most of the species as well as for going through the typescript.

## Order: **PEZIZALES**

Saprophytes; apothecia usually flat, concave or convex, sometimes campanulate or saddle–shaped, sessile or stalked, bright or dark in colour; asci ovoid or cylindric opening by an apical lid; ascospores relatively large, globose or ellipsoid, hyaline or coloured, unseptate, smooth or variously sculptured.

KEY TO THE FAMILIES

Apothecia discoid or cupulate, sessile or sub-sessile.....1. Pezizaceae

Apothecia saddle-shaped or campanulate, usually long stalked..... 2. Helvellaceae.

## Family : PEZIZACEAE

Apothecia flat, convex or cup-like, usually brightly coloured sometimes dark brown or black, sessile or subsessile, rarely long-stalked and then the hymenium concave or flat, externally naked or clothed with hairs or bristles, context fleshy, waxy, cartilaginous or horny ; asci ovoid or cylindric, operculate or bilabiate, 2-to many-spored ; spores globose, ellipsoid or fusiform, hyaline or coloured, smooth or variously sculptured.—*Genera* 50, *species about* 450, *mainly in the temperate region.*

KEY TO THE GENERA

Spores globose
- Coprophilous.....1. *Ascodesmis*
- Humicolous.....2. *Lamprospora*

Spores ellipsoid or fusiform
- Spores reticulate
  - Hymenium bright coloured, spores hyaline.....3. *Aleuria*
  - Hymenium dark coloured, spores smoky brown.....4. *Aleurina*

Spores smooth or verrucose
- Spores coloured
  - Spores free in the ascus.....5. *Ascobolus*
  - Spores united into ball in the ascus.....6. *Saccobolus*

Spores hyaline or subhyaline
- Apothecia less than 1 cm. in diameter
  - Apothecia glabrous
    - Vegetative mycelium superficial.....7. *Pyronema*
    - Vegetative mycelium immersed
      - Apothecia 8-spored
        - Coprophilous.....8. *Ascophanus*
        - Humicolous.....9. *Humarina*
      - Apothecia many-spored.....10. *Rhyparobius*
  - Apothecia hairy or setose
    - Apothecia wholly or partially buried.....11. *Sepultaria*
    - Apothecia superficial
      - Hairs simple (without cross walls).....12. *Lasiobolus*
      - Hairs septate, bristle-like.....13. *Humaria*
- Apothecia exceeding 1 cm. in diameter
  - Apothecia split along one side.....14. *Otidea*
  - Apothecia symmetrical

Apothecia stalked, hairy or tomentose
Apothecia brightly coloured.....15. *Plectania*
Apothecia brown or blackish.....16. *Paxina*
Apothecia sessile or subsessile, not densely hairy
Apothecia acorn cup-like.....17. *Geopyxis*
Apothecia saucer or cup-like.....18. *Peziza*

### 1. **Ascodesmis** van Tiegh.

Apothecia less than 1 mm. in diam., consisting of a cluster of asci and paraphyses; excipulum totally wanting; asci 8-spored; spores pale brown to blackish, becoming sculptured at maturity.—*Species* 2 *or* 3, *in north temperate region.*

1. **Ascodesmis microscopica** (Crouan) Seaver in *Mycologia* 8: 3. 1916 ; Le Gal in *Rev. de Mycol.* 14: 93. 1949.

Apothecia 0.3-0.5 mm. in diameter, pale yellowish; asci pyriform, 8-spored, 60-80 x 30-35 μ; spores globose, dark brown to almost opaque, reticulate, the projections of the epispore giving the outline of the spore a verrucose appearance, 12-17.5 μ in diameter.

On dung of rabbit, Lahore.

### 2. **Lamprospora** de Not.

Apothecia scutellate to discoid, externally smooth or verrucose, hymenium usually concave and brightly coloured; rarely convex and dark coloured ; asci clavate or cylindric, 8-spored ; spores smooth or variously sculptured, hyaline or faintly coloured.—*Species* 40, *in north temperate region.*

1. **Lamprospora trachycarpa** (Curr.) Seaver in *Mycologia* 6: 19. 1914.

Apothecia gregarious, cupulate, up to 1.5 cm. in diameter, externally rough and scabrous; hymenium dark reddish brown becoming black with age; asci cylindric, 250-280 x 13-15 μ ; spores globose, at first hyaline and smooth, becoming pale yellowish and verrucose later on, 16 μ in diameter.

On the ground, Nathia Gali, 27. 9. 1949. no. 2928.

### 3. **Aleuria** Fuckel

Apothecia sessile or stalked, bright coloured, externally smooth or tomentose; asci cylindric, 8-spored; spores ellipsoid, reticulate, hyaline. *Species* 10, *in north temperate region.*

KEY TO THE SPECIES

Spores 20-25 x 9-10 μ ; spore reticulations regular.....1. *A. aurantia*
Spores 10-15 x 7-10 μ ; spore reticulations in form of diagonal or spiral bands.....2. *A. murreeana*

n. of. Jan XI.55.

Vol. I No. I

# BIOLOGIA

June, 1955

Published by
THE BIOLOGICAL SOCIETY OF PAKISTAN
Biological Laboratories, Government College,
LAHORE

COMMONWEALTH MYCOLOGICAL
1 SEP 1966

**Biologia** is published twice a year by The Biological Society of Pakistan, Lahore. The Journal is available in exchange with other Institutions for publications of a similar character.

*Annual Subscription :* Rs. 15. *Single Copy :* Rs. 8.

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1. **Aleuria aurantia** (Pers. ex Fr.) Fckl. *Symb. Myc.*, p. 325, 1869.

Apothecia gregarious, sessile or stalked, up to 2 cm. in diameter, cupulate, externally white, pruinose; hymenium bright orange, asci cylindric, 160-200 x 8-10 μ, 8-spored; spores ellipsoid, 20-25 x 8-10 μ, hyaline, at first smooth, then reticulate, spore reticulations regular, the ridges projecting at the ends of the spores to form apiculi; paraphyses septate, hyaline, swollen to 5.5 μ at the tips.

On the ground, Murree, 8. 8. 1953, no. 7037; 9. 8. 1953, no. 7038; Changla Gali, 25. 9 1948, no. 2927.

2. **Aleuria murreeana** n. sp.

Apothecia dispersa vel aggregata, carnosa, maxime 1 cm. diam.; exteriore subflava, glabra; hymenio umbrino; asci cylindricei, 8-spori, 220 x 12 μ; sporae ellipsoideae, hyalinae, 10-15 x 7-10 μ, reticulatae, reticuli torta fascia ordinati; paraphyses flexae, hyalinae, apice crassiore.

Apothecia scattered or gregarious, fleshy, up to 1 cm. in diameter; exterior pale yellowish, smooth; hymenium ochraceous orange (R); asci cylindric, 8-spored, 220 x 12 μ; spores ellipsoid, hyaline, reticulate, reticulations in the form of diagonal or spiral bands, 10-15 x 7-10 μ; paraphyses flexuous, hyaline, swollen to 7 μ at the tips.

On the ground, Patriata, 20.8.1953, no. 8029; Murree 18-8-1953, no. 8014; type.

**4. Aleurina** Sacc. & Syd.

Apothecia brownish black to almost black, fleshy, asci cylindric or clavate, 8-spored; spores ellipsoid, smoky brown at maturity, with distinct or indistinct reticulations.—*Species* 5, *in north temperate region.*

*Aleurina pakistanica.* Spores x 500.

1. **Aleurina pakistanica** n. sp.

Apothecia aggregata, cupulata, regulariter vel irregulariter formata, maxime 1 cm. diam., hymenio brunneo vel nigro; exteriore pallido, glabro; asci cylindricei, 200 x 10 μ, 8-spori; sporae ellipsoideae, 15-24 x 8-12 μ, primum hyalinae et glabrae, demum fusco-griseae et reticulatae, reticulis non integris, formis curvatis et diffendentibus in omnes partes; paraphyses hyalinae, solidae, apices crassiore.

Apothecia gregarious, cupulate, regular or becoming irregular due to mutual pressure, up to 1 cm. in diameter; hymenium dark brown or almost black ; exterior pale, smooth ; asci cylindric, 200 x 10 μ , 8-spored ; spores ellipsoid, at first hyaline and smooth, finally becoming smoky brown and reticulate, reticulations very imperfect and broken, the ridges sinuate and extending in all directions, 15-24 x 8-12 μ; paraphyses stout, swollen to 7 μ at the tips.

On the ground, Nathia Gali, Murree Hills, 26. 9. 1949, no. 2937, type.

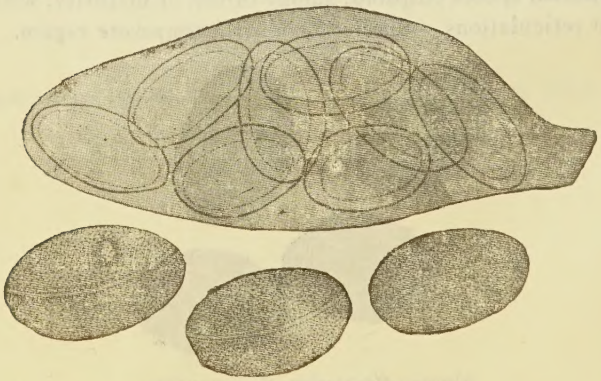
### 5. **Ascobolus** Pers.

Apothecia coprophilous or humicolous, fleshy or waxy ; asci 4-to 8-spored, much protruding above the surface ; spores violet at maturity, ellipsoid to subglobose, variously sculptured; paraphyses filiform or clavate usually adhering together.—*Species* 25, *widespread.*

KEY TO THE SPECIES

Spores 45-55 x 25-30 μ..... 1. *A. immersus*
Spores not more than 30 x 15 μ
Apothecia up to 5 mm. in diam..... 2. *A. stercorarius*
Apothecia not exceeding 1 mm. in diam..... 3. *A. glaber*
Apothecia exceeding 5 mm. and up to 2.5 cm. 4. *A. magnificus*

1. **Ascobolus immersus** Pers. ex Fr. *Syst. Myc.* 2 : 164. 1822.

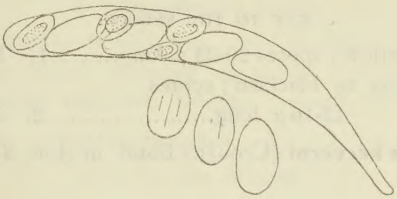


*A. immersus*, ascus and spores, x500.

Apothecia 1-2 mm. in diameter, greenish yellow; asci few, clavate, 130-150 x 53-69 μ, 8-spored; spores 2-seriate, broadly ellipsoid, violet or brown, 44-55 x 27-30 μ ; paraphyses slender, not enlarged at the tips.

On cow dung, Lahore.

2. **Ascobolus stercorarius** (Bull. ex Fr.) Schroet. *Krypt. Fl. Schles.* 3 (2) : 56, 1893.



*A. stercorarius.* Ascus and spores x 450

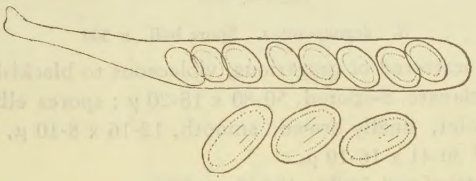
Apothecia gregarious, sessile, yellowish or yellowish green ; exterior furfuraceous, 0.5 mm. in diameter ; asci much protruding above the surface, clavate, 120-180 x 20-27 μ, 8-spored ; spores elliptic, at first hyaline then dark violet, longitudinally striated, 18-25 x 9-12 μ; paraphyses filiform, septate, 2-4 μ thick.

On the ground, Lahore, 29-2-48 ; on cow dung, Nathia Gali, 26-9-49, no. 2948.

3. **Ascobolus glaber** Pers. ex Fr. *Syst. Myc.* 2 : 164, 1822.

Apothecia gregarious, 0.2-0.5 mm. in diam.; exterior smooth; asci clavate, 200-245 x 20-25 μ, 8-spored; spores elliptic, at first hyaline then violet, longitudinally striated, 18-24 x 8-12 μ; paraphyses filiform, septate, 3-4 μ thick.

4. **Ascobolus magnificus** B. O. Dodge in *Mycologia* 4 : 218, 1912.



*A. magnificus.* Ascus and spores, x 500.

Apothecia scattered or gregarious, sessile, margin involute , hymenium greenish yellow, up to 2.5 cm. in diameter ; asci cylindric-clavate, 200-300 x 18-25 μ, 8-spored ; spores ellipsoid, at first hyaline then pale lilac, finally violet, smooth, 20-25 x 12-14 μ ; paraphyses linear, slightly swollen at the tips.

On cow dung, Ladhar ; Lahore, 16-11-49, no. 2977, 23-11-50, no. 4208; Sialkot, 2-11-53, no. 12047.

6. **Saccobolus** Boud.

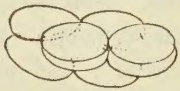
Apothecia small, fleshy or waxy; hymenium roughened by the projecting asci ; asci cylindric, 4-to 8-spored ; spores purple or brown at

maturity, subglobose or ellipsoid, united into a ball within the ascus. —*Species* 10, *esp. in temperate region.*

KEY TO THE SPECIES

Apothecia golden yellow ; spores 20-23 μ long.....1. *S. kerverni*
Apothecia violaceous to blackish ; spores 12-16 μ long.....2. *S. depauperatus*

1. **Saccobolus kerverni** (Crouan) Boud. in *Ann. Sci. Nat.* Ser. 5, 10 : 229, 1869.

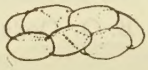


*S. kerverni.* Spore ball, x 500

Apothecia scattered, golden yellow, 0.5-1 mm. in diam. ; asci cylindric-clavate, 100-150 x 22-28 μ, 8-spored ; spores elliptic, at first hyaline then violet, smooth, 20-23 x 9-14 μ, united into a ball ; spore ball 48-51 x 18.5-23 μ.

On cow dung, Shadara, Sialkot, Lahore.

2. **Saccobolus depauperatus** (Berk. & Br.) Rehm in *Hedwigia* 22 : 37, 1883.



*S. depauperatus.* Spore ball, x 500

Apothecia scattered or gregarious, violaceous to blackish, 0.2-0.5 mm. in diam. ; asci clavate, 8-spored, 50-80 x 18-20 μ ; spores elliptic, at first hyaline then violet, finally brown, smooth, 12-16 x 8-10 μ, united into a ball ; spore ball 30-41 x 16-19 μ.

On mud plaster of wall, Ladhar, 13.8.48, no. 2606.

### 7. **Pyronema** Carus

Vegetative mycelium forming a conspicuous web on burnt ground. Apothecia 1-2 mm. in diam.; hymenium convex ; excipulum absent ; asci cylindric, 8-spored ; spores ellipsoid, hyaline, smooth.—*Species* 2 *or* 3, *widespread.*

1. **Pyronema confluens** (Pers. ex Fr.) Tul. *Fung. Carp.* 3 : 197, 1864.

Apothecia up to 1.5 mm. in diam., yellowish to pale orange, seated on a white mycelium ; asci cylindric, 150 x 10-14 μ ; spores ellipsoid, hyaline, smooth, 10–13 x 5–8 μ ; paraphyses enlarged at the tips, with orange granules.

On burnt ground, Ladhar ; Lahore.

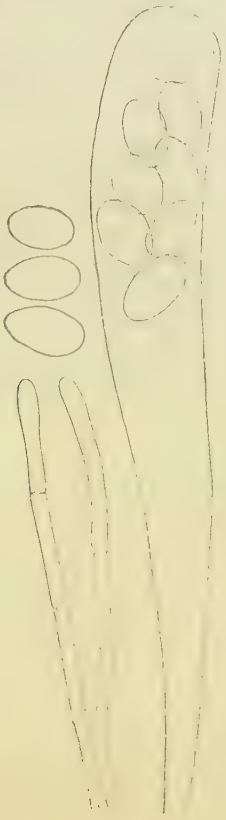
### 8. **Ascophanus** Boud.

Coprophilous ; apothecia less than 1 mm. in diam., externally smooth or slightly granular, bright coloured or rarely brownish ; asci cylindric, 4- to 8- spored ; spores ellipsoid, hyaline, smooth or minutely rough. —*Species about* 40, *in temperate region.*

KEY TO THE SPECIES

Asci clavate..... 1. *A. carneus*
Asci cylindric
Apothecia orange..... 2. *A. granulatus*
Apothecia yellowish to ochraceous..... 3. *A ochraceous*

1. **Ascophanus carneus** (Pers.) Boud. in *Ann. Sci. Nat.* ser. 5, 10 : 250, 1869.



*A. carneus.* Ascus, paraphyses and spores, x 500

Apothecia 0.5-1 mm. in diameter, flesh coloured; asci clavate, tapering below into stem like base, 200-250 x 24-30 μ, 8-spored; spores 2-seriate, or crowded, ellipsoid, hyaline, finely verrucose, 15.5-20 x 11-12 μ; paraphyses stout, septate, with granular contents, swollen to 4-4.5 μ at the tips.

On cow dung, Lahore.

2. **Ascophanus granulatus** (Bull. ex Fr.) Speg. in *Michelia* 1 : 235, 1879.

Apothecia densely gregarious, orange in colour; exterior minutely granular, pale orange; asci cylindric, 8-spored, 150-200 x 9-12 μ; spores 1-seriate, elliptic, hyaline, 10-14 x 5-7 μ.

On cow dung, Murree, August 1948, no. 2499; 13.7.50, no. 2693; Patriata, 18.8.53, no. 12049.

3. **Ascophanus ochraceous** (Crouan) Boud. in *Ann. Sci. Nat.* ser. 5, 10 : 247. 1866.

Apothecia gregarious, yellow or ochraceous, 0.5–1 mm. in diameter; exterior smooth, pale yellow; asci cylindric, 88–100 x 9–12 μ; spores ellipsoid, smooth, hyaline to pale yellowish, 12–14.5 x 7–8.5 μ

On cow dung, Nathia Gali, 26. 9. 48, no. 2948; Patriata, 18. 8. 53, no. 8039.

### 9. **Humarina** Seaver

Humicolous. Apothecia usually less than 1 cm. in diameter, generally bright coloured, rarely brown or black; asci clavate or cylindric, 4- to 8-spored; spores ellipsoid or fusiform, hyaline, smooth or verrucose. *Species 50, in north temperate region.*

KEY TO THE SPECIES

Apothecia light coloured (white, yellow, red or violaceous).
- Spores elliptic
  - Growing on stones of *Zizyphus* ..... 1. *H. zizyphi*
  - Growing on the ground
    - Spores 18-20 x 10-11 μ ..... 2. *H. semi-immersa*
    - Spores 13.5-17 x 7-10 μ ..... 3. *H. luteola*
- Spores fusoid
  - Hymenium bright orange; asci 4-spored ..... 4. *H. tetraspora*
  - Hymenium violaceous; asci 8-spored ..... 5. *H. gerardii*

Apothecia dark coloured (brownish black or plumbeous black)
- Paraphyses straight
  - Hymenium Saccardo's umber ..... 6. *H. umbrina*
  - Hymenium violet slate or plumbeous ..... 7. *H. plumbeoatra*
- Paraphyses hooked ..... 8. *Humarina* sp.

1. **Humarina zizyphi** Cash in *Mycologia* 40 : 727, 1948.

Apothecia obconic to turbinate, substipitate, 1-4 mm. in diam., margin slightly undulate and inrolled; hymenium scarlet (R), carrot red to ochraceous tawny when dry; exterior smooth, concolourous ; asci cylindric, long stalked, 100-150 x 13-15 μ ; spores hyaline, smooth, oblong-ellipsoid, filled with many oil globules, 20–25 x 11-12 μ ; paraphyses hyaline, branched near the apex, slightly swollen to 2-3 μ at the tips.

On stones of *Zizyphus jujuba*, Ladhar (Sheikhupura), 23. 9. 41, no. 419; 18. 9. 50, no. 2935.

2. **Humarina semi-immersa** (Karst.) Seaver, *North American Cup Fungi (Operculates)* p. 130, 1942.

Apothecia partially buried in the ground, up to 10 mm. in diam.; hymenium bright yellow to pale ochraceous; exterior floccose, pale yellow; asci cylindric, 250-320 x 16-20 μ; spores hyaline, smooth, elliptic, 18-20 x 10-12 μ ; paraphyses hyaline, slightly swollen to 2 μ at the tips.

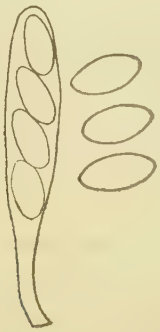
On the ground, Ladhar (Sheikhupura), 21. 12. 52, no. 4988.

3. **Humarina luteola** (Torrend) Cash apud Ahmad in *Sydowia* 4 : 83, 1950.

Apothecia sessile, caespitose, partially immersed, irregularly convoluted due to mutual pressure, up to 5 mm. in diam.; hymenium ochraceous orange to ochraceous tawny (R); exterior smooth, concolourous; asci cylindric, 8-spored, 200-240 x 12 μ ; spores hyaline, smooth, elliptic, 13.5-17 x 7-10 μ ; paraphyses hyaline, swollen to 5 μ at the tips.

On the ground, Lahore, 11.1.48, no. 2235.

4. **Humarina tetraspora** (Fckl.) Seaver, *North American Cup Fungi (Operculates)* p. 134, 1942.



*H. tetraspora*. Ascus and spores, X 500

Apothecia sessile, up to 3 mm. in diameter; hymenium apricot orange (R); exterior pale yellow, smooth; asci cylindric, 4-spored, 130-140 x 12 μ; spores hyaline, smooth, broadly elliptic to fusoid, 20-22 x 10-12 μ; paraphyses hyaline, swollen to 5 μ at the tips.

On the ground, Lahore, 29. 2. 48, no. 2263

5. **Humarina gerardii** (Cke.) Seaver, *North American Cup Fungi (Operculates)* p.138, 1942.

Apothecia sessile, up to 5 mm. in diameter; hymenium vinaceous drab (R); exterior smooth, pale violaceous; asci cylindric, 8-spored, 250–300 x 14-16 μ; spores hyaline, smooth, fusoid, 27-34 x 9-10 μ; paraphyses rather stout, swollen to 4 μ at the tips.

On the ground, Patriata, 18.8.53, no. 7055.

6. **Humarina umbrina** Cash in *Mycologia* 40 : 726, 1948.

Apothecia sessile, more or less plicate, 7-8 mm. in diameter; hymenium Saccardo's umber (R), drying sepia (R); exterior smooth, concolourous; asci cylindric, 8-spored, 200-250 x 11 μ; spores hyaline, ellipsoid, smooth, 12-15 x 7-9 μ; paraphyses flexuous, swollen to 4-5 μ at the tips.

On the ground, Lahore, 24.10.47, no. 2225.

7. **Humarina plumbeoatra** Cash in *Mycologia* 40 : 726, 1948.

Apothecia sessile to partly immersed in the soil, 1.5-3 mm. in diam., hymenium dark violet slate or urania blue to plumbeous black (R); exterior smooth, concolourous; flesh purple when crushed; asci cylindric, 8–spored, 130–175 x 12–15 μ; spores broadly ellipsoid, smooth, 13–14 x 7–9 μ; paraphyses slender, gradually enlarged to 2.5–3.5 μ at the tips.

On the ground by the side of water course, Ladhar (Sheikhupura). 8. 7 46, no. 1640; 15. 9. 47, no. 2100; 29. 7. 49, no. 2716; 9 8. 50, no. 2945.

8. **Humarina** sp.

Apothecia sessile or subsessile, up to 5 mm. in diam.; hymenium fuscous black (R); exterior fuscous (R), clothed with branched, septate, appressed hairs; asci cylindric, 8–spored, 192–200 x 8–9 μ; spores elliptic, smooth, 9–14 x 5–8 μ; paraphyses slender, gradually enlarged to 3–4 μ at the tips and characteristically hooked.

On the ground, Nathia Gali, 27. 9. 49, no. 2933.

10. **Rhyparobius** Boud.

Apothecia very small; hymenium usually roughened by the protruding asci; exterior smooth; asci broad–clavate or ovoid, polysporous; spores hyaline, ellipsoid, usually enveloped by a mucilaginous sheath. —*Species* 10, *in temperate region.*

1. **Rhyparobius crustaceus** (Fckl.) Rehm in *Ber. Naturh. Ver. augsburg.* 26: 17, 1881.

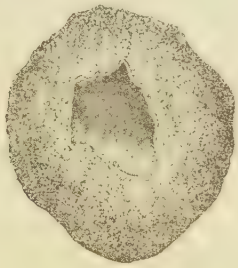
Coprophilous. Apothecia gregarious, about 1 mm. in diam.; hymenium roughened by the protruding asci, pale ochraceous yellow, exterior white or concolourous; asci about 12 in an apothecium, clavate, 60–70 x 20–22 μ, many-spored; spores hyaline, ellipsoid, 7–9 x 4–4.5 μ; paraphyses delicate.

On dung, Lahore. Rare.

### 11. **Sepultaria** Massee

Apothecia cup shaped, partially to entirely buried in the soil, becoming partially exposed at maturity; exterior clothed with soft or bristly hairs; hymenium white, orange or red; asci 8-spored; spores ellipsoid, hyaline, smooth.—*Species* 10, *in north temperate region.*

1. **Sepultaria arenicola** (Lev.) Mass., *Brit. Fung. Flora* 4: 389, 1895.



*S. arenicola.* Apothecium, x I.

Apothecia gregarious, at first globose and closed, entirely buried in the soil, later opening at the apex and appearing as holes in the ground, margin entire or irregularly split, 2–6 cm. in diameter; exterior clothed with dense brown hairs closely binding the soil particles; hymenium white or cream coloured; asci cylindric, 8-spored, 230–250 x 16–20 μ; spores ellipsoid, hyaline, smooth, 28–32 x 14–16 μ; paraphyses swollen to 4–7 μ at the tips.

On the ground, Bahrain (Swat State), 14. 4. 54, no. 9070.

### 12. **Lasiobolus** Sacc.

Apothecia clothed with hyaline or yellowish, rigid, non-septate hairs; asci strongly projecting above the surface, cylindric-clavate, 8-spored; spores hyaline, smooth, ellipsoid. *Species* 8, *in temperate region.*

1. **Lasiobolus equinus** (Muell.) Karst. *Acta Soc. Fauna Fl. Fenn.* 2: 122, 1885.

Apothecia gregarious, up to 1 mm. in diameter, hymenium hyaline to pale orange; setae hyaline to pale yellowish, non-septate, up to 450 μ long and 20 μ broad at the base; asci cylindric, 180–250 x 16–20 μ; spores ellipsoid, smooth, hyaline, 20–25 x 12–13 μ; paraphyses flexuous, not dilated at the tips.

On richly manured soil, Charehan, Murree Hills, 14-8-53, no. 7041.

## 13. **Humaria** Fckl.

Apothecia discoid, superficial, up to 1 cm. in diameter; exterior clothed with setae, at least at the edge; hymenium red, yellow, brown or white; setae septate, hyaline or coloured, usually rigid; asci 8-spored; spores ellipsoid or fusoid, smooth or verrucose.—*Species* 60, *in north temperate region.*

KEY TO THE SPECIES

Hymenium red, yellow or brown
- Humicolous
  - Setae very short, inconspicuous; spores 15–20 x 9–12 μ ..... 1. *H. ahmadii*
  - Setae well developed, bristly; spores 20–24 x 12–15 μ ..... 2. *H. scutellata*
- Coprophilous ..... 3. *H. pulcherrima*

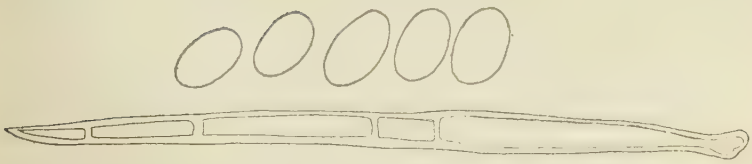
Hymenium white
- Spores verrucose
  - Apothecia 2–3 cm. in diam ..... 4. *H. hemisphaerica*
  - Apothecia 2–5 mm. in diam ..... 5. *H. gregaria*
- Spores smooth ..... 6. *H. albospadicea*

**Humaria ahmadii** Cash in *Mycologia* 40 : 725, 1948.

Apothecia sessile, convex, 1–3 mm. in diameter, bright red, fading to olive gray or nearly white in dried specimens; asci cylindric, 8-spored, 180–190 x 18–20 μ; spores broadly elliptic, hyaline, coarsely verrucose, usually only 4 becoming mature, 15–20 x 9–12 μ; paraphyses flexuous, unbranched, enlarged at the tips to 5-6 μ; setae inconspicuous, pale brown, subacute, simple or 1–2 septate, 75–110 x 8–11 μ.

On the ground, Lahore, 24. 10. 47, no. 2226; Changla Gali, 24. 9. 49, no 2925; Shogran (Kagan Valley), 22. 8. 49, no. 2966; Kalam (Swat State).

2. **Humaria scutellata** (L.) Fuck. *Symb. Myc. p.* 321, 1869. Syn. *Patella scutellata* (L.) Morgan in *Jour. Myc.* 8 : 187, 1902; *Lachnea scutellata* (L.) Gillet, *Champ. Fr. Discom.* p. 75, 1879.



*H. scutellata.* Setae, x 320; spores, x500

Apothecia usually crowded, sessile, up to 1 cm. in diam., with a fringe of long brown setae, hymenium bright red, fading to yellow or nearly white in dried specimens; asci cylindric, 8 spored, 200-225 x 12-15 $\mu$; spores hyaline, ellipsoid, finely verrucose, 20-24 x 12-15 $\mu$; paraphyses flexuous, enlarged to 7–10 $\mu$ at their tips, setae septate, reddish brown, 0.5–1 mm. long and up to 40 $\mu$ broad at the base.

On rotten wood; Murree, August 1948, no. 2402; Nathia Gali, 27. 9. 49, no. 2931; Shogran, 22. 8. 49, no. 2961; Naran-Batakundi, 26. 8. 49, no. 2559; Swat State.

3. **Humaria pulcherrima** Speg. in *Michelia* 1 : 237, 1878.

Apothecia densely crowded, short cylindric, up to 1 mm. in diam.; hymenium bright yellow; exterior pale yellow, sparsely setose; asci cylindric, 8-spored, 200-230 x 15-20 $\mu$; spores hyaline, smooth, 20-22 x 10-12 $\mu$; paraphyses flexuous, unbranched, slightly enlarged at the tips, yellow; setae rigid, pale brown, septate, reaching a length of 150 $\mu$ and a diam. of 15 $\mu$ at their bases.

On cow dung, Shahdara, 14-2-48, No. 2052.

4. **Humaria hemisphaerica** (Wigg. ex Fr.) Fckl. *Symb. Myc.* p. 322, 1869. —Syn. *Patella albida* (Schaeff.) Seaver in Brenckle *Fungi Dakot.* No. 407, 1916.

Apothecia scattered or in groups, shallow cup-shaped, up to 3 cm. in diameter and 1 cm. deep, externally entirely clothed with tufted hairs; hymenium white becoming yellowish-brown when dry; asci cylindric, tapering below into a stem-like base, 300-320 x 15-18 $\mu$; spores ellipsoid, verrucose, hyaline, 25-27 x 12-15 $\mu$; paraphyses swollen to 6-8 $\mu$ at the apex; setae septate, sharp pointed, dark brown, 400-450 $\mu$ long, reaching a breadth of 20 $\mu$ at the base.

On the ground, Mt. Ilam (Swat State), 12. 8. 51, no. 7011.

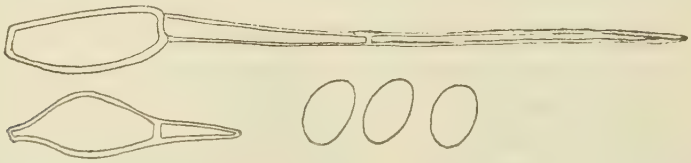
5. **Humaria gregaria** Rehm apud Winter in *Flora* 55 : 508, 1872.

Apothecia gregarious, 4-5 mm. in diameter, hymenium white; exterior covered with setae; asci cylindric, 300 x 17 $\mu$; spores hyaline, elliptic, minutely verrucose, 20-27 x 10-13 $\mu$; paraphyses slender; slightly enlarged at the tips to 5 $\mu$; setae borne in clusters and appressed to the

sides of the apothecium, septate, sharp pointed, pale brown, reaching a length of 300 μ and breadth of 12 μ at their bases.

On the ground, Kalam (Swat State), 22. 8. 52, no. 4779.

6. **Humaria albospadicea** (Grev.) Cash n. comb. Syn. *Peziza albospadicea* Grev. *Fl. Edinb.*, p. 420, 1824.



*H. albospadicea.* Setae and spores, x 500

Apothecia gregarious, reaching a diameter of 5 mm., hymenium white; exterior clothed with a dense covering of setae; asci cylindric, gradually attenuated towards the base, 350 x 22 μ; spores hyaline, ellipsoid, smooth, 18-20 x 12-14 μ; paraphyses little enlarged at the tips; setae rigid, pale brown, septate, sharply pointed, up to 200 μ long, swollen at the base to 20 μ.

On the ground, Patriata, 18. 8. 53, no. 8018; 19. 8. 53, no. 8020; Nathia Gali, 26. 9. 49, no. 2951; Murree, 12. 8. 53, no. 12052; 20. 8. 53, no. 12054.

## 14. **Otidea** Fckl.

Apothecia sessile or stipitate, gregarious, often caespitose, occasionally fused at the base, elongate, ear-shaped or truncate, split to the base on one side; asci cylindric, 8-spored; spores elliptic, hyaline, smooth. —*Species* 15, *in north temperate region.*

**Otidea leporina** (Batsch ex Fr.) Fckl. *Symb. Myc.* p. 329, 1869.

*O. leporina.* Apothecium, x 1; spores and paraphyses, x 500.

Apothecia gregarious or caespitose, elongate, ear-shaped, split on one side to the base, 1–4 cm. high and 1–3 cm. wide, narrowed below

into a stalk, exterior hazel (R), interior wood brown to sayal brown (R); asci cylindric, 8–spored, 110-140 x 9-12 μ; spores elliptic, smooth, 12–14 x 6–8 μ; paraphyses filiform, hyaline, hooked or bent at their apices.

On the ground, Murree, August 1948, no. 2540; Sharhan (Kagan Velley), 25. 7. 51.

### 15. Plectania Fckl.

Apothecia stipitate or almost sessile, externally more or less hairy, hairs hyaline or pale yellow, hymenium bright coloured ; asci cylindric, 8–spored; spores ellipsoid, hayline or subhyaline, smooth; paraphyses slender, filiform.—*Species 2 or 3, in north temperate region.*

KEY TO THE SPECIES

Spores 19–24 x 9–14 μ ..... 1. *P. occidentalis*
Spores 20–35 x 10–12 μ ..... 2. *P. coccinea*

1. **Plectania occidentalis** (Schw.) Seaver, *North American Cup Fungi (Operculates)* p. 193, 1942.

Apothecia gregarious or caespitose, cupulate to discoid, 1 cm. in diam., stipitate, externally white; hymenium bright red; stipe very variable in length; asci cylindric, tapering towards the base, 250-300 x 10–15 μ; spores ellipsoid, hyaline, 19–24 x 9-14 μ; paraphyses swollen to 3-5 μ at the tips.

*P. occidentalis.* Apothecia, x 1.

On sticks lying on or buried in the ground, Murree, 23. 9. 49, no. 2936; Patriata, 20. 8. 53, no. 8028. Very common.

2. **Plectania coccinea** (Scop. ex Fr.) Fckl. *Symb. Myc.* p. 324, 1869.

Apothecia gregarious or scattered, immersed, deeply cup-shaped, margin incurved and toothed, up to 2 cm. in diameter, sessile or with about 3 cm. long stipe; exterior white, covered with debris; hymenium scarlet fading in the herbarium; asci cylindric, 8-spored, 350-400 x 12–14 μ; spores ellipsoid, smooth, hyaline, 25-35 x 10-12 μ; paraphyses slender, flexuous, not swollen at the tips.

Attached to buried sticks, Bahrain (Swat State), 14. 4. 54, no. 9072.

### 16. Paxina Kze.

Apothecia stipitate, cupulate, externally hairy or tomentose, tough and leathery, stipe even or lacunose; asci cylindric, 1-spored; spores ellipsoid to fusiform, smooth or rough, hyaline. - *Species 20, in north temperate region.*

KEY TO THE SPECIES

Stipe slender, even..... 1. *P. hispida*
Stipe lacunose or corrugated
Corrugations extending to the margin of the apothecium..... 2. *P. acetabulum*
Corrugations extending only up to the base of the apothecium..... 3. *P. sulcata*

1. **Paxina hispida** (Schaeff. ex Fr.) Seaver, *North American Cup Fungi (Operculates)* p. 205, 1942.

Apothecie stipitate, up to 3 cm. in diameter and up to 1 cm. in depth, externally densely whitish tomentose; hymenium brown; stipe up to 3 cm. long and 3 mm thick, even ; spores ellipsoid, smooth, hyaline, 20–25 x 12–14 μ; paraphyses gradually enlarged to 6 μ in diameter.

On the ground, Shogran (Kagan Valley), 22. 8. 49, no. 2963; Changla Gali, 25. 9. 49, no. 2932.

2. **Paxina acetabulum** (L. ex Fr.) Kuntze, *Rev. Gen. Pl.* 2 : 864, 1891.

Apothecia stipitata, up to 10 cm. in diameter and 3 cm. in depth, externally conspicuously corrugated, the corrugations extending up to the margin : hymenium smoky grey or black ; stipe up to 1.2 cm. long and 1 cm. thick, deeply lacunose ; spores ellipsoid, smooth, 16–18 x 8–9 μ ; paraphyses enlarged to 8–10 μ in diameter at the apex.

On the ground, Murree, August 1948, no. 2403; Patriata, 18. 8. 53; Bahrain (Swat State), 14. 4. 54, no. 9071.

3. **Paxina sulcata** (Pers. ex Fr.) Kuntze, *Rev. Gen. Pl.* 2 : 864, 1891.

Apothecia stipitate, reaching a diameter of 2 cm. and a depth of 1 cm.; externally minutely rough, brownish; hymenium brownish black; stipe about 1 cm. long, lacunose, corrugations extending to the base of the apothecium ; spores ellipsoid, smooth, 15–20 x 12–14 μ; paraphyses thickened to 7 μ at the apex.

On the ground, Murree; Patriata; Nathia Gali.

17. **Geopyxis** (Pers.) Sacc.

Apothecia medium sized, buried in the soil when young but becoming exposed at maturity, shaped like an acorn cup, margin entire or lobed, stipitate, stipe short and slender; asci cylindric, 8-spored; spores smooth, hyaline, ellipsoid.—*Species 5, in north temperate region.*

KEY TO THE SPECIES

Apothecia verrucose externally; spores 14–20 x 8–12 μ.....1. *G. bronca*
Apothecia smooth; spores 14–16 x 7–10 μ.....2. *G. cupularis*

1. **Geopyxis bronca** (Peck) Seaver, *North American Cup Fungi (Operculates)* p. 213, 1928.

Apothecia gregarious, sessile or substipitate, externally pale yellow, verrucose due to coarse warts, 2–3 cm. in diameter; hymenium pale yellow or lemon yellow; asci 140–190 x 10–15 μ; spores ellipsoid, hyaline, smooth, 14–20 x 8–12 μ ; paraphyses swollen to 5–8 μ at the tips.

On the ground, Murree, August 1948, no. 2425; Nathia Gali, 27. 9. 49, nos. 2929 & 2949; Shogran, 22. 8. 49, no. 2960; Patriata, 20. 8. 53; Mt. Ilam (Swat State), 12 .8. 51, no. 7012.

2. **Geopyxis cupularis** (L. ex Fr.) Sacc. *Syll. Fung.* 8 : 72, 1889.

Apotheoia densely gregarious, irregularly contorted due to mutual pressure, up to 7 mm. in diameter ; hymenium deeply concave, cream buff to honey yellow (R), exterior smooth, concolourous; asci cylindric, 8–spored, 220–250 x 11–15 μ; spores ellipsoid, hyaline, smooth, 14–16 x 7–10 μ; paraphyses slender, hyaline, swollen to 3–5 μ at the tips.

Among needles of *Cedrus deodara*, Patriata, 20. 8. 53, no. 8014.

18. **Peziza** Dill. ex Fr.

Apothecia usually cupulate, occasionally discoid or repand, 1–10 cm. in diameter, externally smooth; asci cylindric, 8–spored; spores ellipsoid, hyaline, smooth or sculptured.—*Species* 50, *widespread.*

KEY TO THE SPECIES

Spores verrucose..... 1. *P. badia*
Spores smooth..... 2. *P. repanda*

1. **Peziza badia** Pers. ex Fr. *Syst. Myc.* 2 : 46, 1822.

Apothecia scattered, sessile, up to 6 cm. in diameter ; hymenium light drab to drab, fuscous or warm sepia (R), exterior tan coloured or concolourous, smooth; asci cylindric, tapering towards the base ; spores ellipsoid, hyaline, verrucose, 13–18.5 xo 7–9.5 μ; paraphyses enlarged to 5–9 μ at the tips.

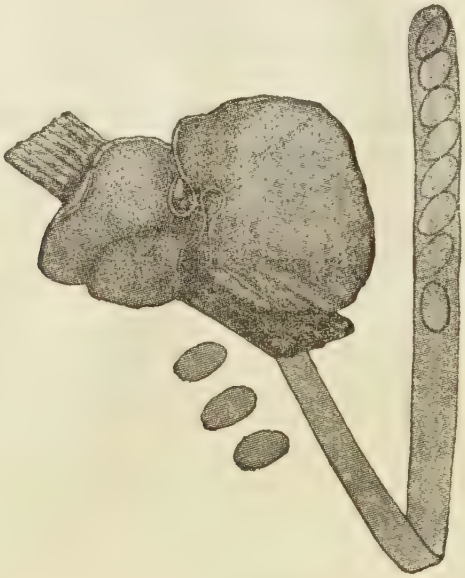
*P. badia.*
Spores, x 500

On the ground, Ladhar (Sheikhupura), Nathia Gali, Murree, Patriata, Shogran, Swat State. Very common.

2. **Peziza repanda** Wahl. ex Fr. *Syst. Myc.* 2 : 51, 1822.

Apothecia cupulate, becoming repand at maturity, reaching a diameter of 10 cm.; exterior white, smooth; hymenium pale brown; asci

cylindric, 8-spored, 200–220 x 12–14 μ; spores hyaline, ellipsoid, smooth, 14–19 x 9–12 μ ; paraphyses not swollen at the tips.



*P. repanda*. Apothecium, x 1; ascus and spores, x 500

On rotten coniferous logs, Shogran, 14. 8. 51, no. 2952; Dunga Gali, 16. 8. 54, no. 10076; common.

## Family **HELVELLACEAE**

Apothecia stipitate, pileus columnar, campanulate or saddle-shaped, free from or attached to the stipe; hymenial surface smooth, coarsely pitted, longitudinally ribbed or gyrosely folded; stipe even, lacunose or fluted, smooth or pubescent; asci cylindric, 2- to 8-spored; spores ellipsoid, smooth or sculptured, hyaline.—*Genera* 6, *species about* 50, *mostly in north temperate region.*

KEY TO THE GENERA

Hymenial surface coarsely pitted..... 1. *Morchella*
Hymenial surface not coarsely pitted.
Pileus campanulate..... 2. *Verpa*
Pileus saddle-shaped or irregularly folded..... 3. *Helvella*

### 1. **Morchella** Dill. ex Fr.

Apothecium growing down the side of the upper part of the stipe and with its surface thrown into strong longitudinal and transverse folds, so as to be coarsely pitted; pits rounded or elongated, entirely lined by the hymenium; hymenium yellowish to brown; asci cylindric, 8-spored; spores ellipsoid, smooth, hyaline.—*Species about* 15, *in temperate region.*

KEY TO THE SPECIES

Pileus 4–8 cm. long
Pits large, shallow, ribs thin ; stipe enlarged at the base..... 1. *M. crassipes*
Pits small, deep, ribs thick; stipe not swollen at the base
Pileus subglobose or only slightly elongated... 2. *M. esculenta*
Pileus strongly tapering upwards..... 3. *M. conica*
Pileus not exceeding 3 cm. in length..... 4. *M. deliciosa*

1. **Morchella crassipes** Vent. ex Fr. *Syst. Myc.* 2 : 7, 1822.

Pileus elongated and subconic, up to 10 cm. long and 7 cm. in diam., pits rounded or irregulary elongated, up to 1 cm. in diam., ribs thin; stipe up to 10 cm. long and 6 cm. thick at the base, tapering upwards, yellowish, even; asci cylindric 180–200 x 16–20 μ; spores ellipsoid, hyaline, 18–20 x 12–14 μ.

On the ground, Bahrain (Swat State), 15. 4. 54.

2. **Morchella esculenta** (L. ex Fr.) Fr. *Syst. Myc.* 2 : 6, 1822.

Pileus subglobose, rarely somewhat ovoid, apex obtuse, up to 10 cm. long and 6 cm. in diam ; pits rounded, or somewhat elongate with thick ribs, brown; stipe up to 5 cm. long, 3 cm. thick, yellowish ; asci cylindric, 200–320 x 18–20 μ ; spores ellipsoid, hyaline, 18–22 x 12–14 μ.

On the ground, Murree, April 1952 (leg. I. I. Chaudhuri).

3. **Morchella conica** Pers. ex Fr. *Syst. Myc.* 2: 7, 1822.

Pileus elongated and subconic, tapering towards the apex, up to 8 cm. long and 3 cm. in diam.; pits elongated, with thick ribs, brown ; stipe up to 5 cm. long, 3 cm. thick, yellowish or white ; finely pubescent ; asci cylindric, 220 x 18 μ ; spores ellipsoid, hyaline, 18–22 x 12–14 μ.

On the ground, Shogran (Kagan Valley,) May 1952, (leg. I. I. Chaudhuri).

4. **Morchella deliciosa** Fr. *Syst. Myc.* 2 : 8, 1822.

Pileus conic or obconic, up to 3 cm. long and 1.5 cm. in diam., pits usually elongated, black; stipe white, about 1 cm. long and 6 mm. thick; asci cylindric, 200 x 16 μ; spores ellipsoid, hyaline, smooth, 18–22 x 8–10 μ.

On the ground, Murree, April 1952 ; (leg. I. I. Chaudhuri).

*M. conica*
Apothecium, × 1.

## 2. **Verpa** Swartz ex Fr.

Pileus campanulate, free from the stipe ; hymenial surface even or longitudinally ribbed ; stipe stout, hollow, even, smooth or pubescent ; asci cylindric or clavate, 2-to 8-spored ; spores ellipsoid, smooth, hyaline. *Species* 5, in *north temperate region.*

1. **Verpa bohemica** (Krombh.) Schroet. *Krypt. Fl. Schles.* 3 : 25, 1893.

Pileus campanulate, up to 4 cm. long, and 3 cm. in diam., hymenial surface folded into longitudinal and anastomosing ribs, yellowish to brown ; asci cylindric, 2-spored, 200 x 26 μ ; spores ellipsoid, hyaline, smooth, 60-80 x 17-22 μ.

On the ground, Murree.

*V. bohemica.* Apothecium, x 1

## 2. **Helvella** L. ex Fr.

Pileus mitrate or saddle-shaped, even, the margin reflexed and free from the stipe ; stipe even, lacunose or strongly fluted ; asci cylindric, 8-spored; spores ellipsoid, hyaline, smooth.—*Species* 25, *in north temperate region.*

KEY TO THE SPECIES

Stipe distinctly fluted

Pileus dark coloured, the stipe smoky.....1. *H. mitra*

Pileus and stipe white.....2. *H. crispa*

Stipe not fluted

Pileus and stipe smooth, fleshy.....3. *H. elastica*

Pileus and stipe hairy, tough.....4. *H. ephippium*

1. **Helvella mitra** Schaeff. ex Fr. *Syst. Myc.* 2 : 15, 1822.-Syn. *H. lacunosa* Afz. *Sv. Vet. Akad. Handl. p.* 305, 1783.

Pileus mitrate or irregularly saddle-shaped, the margin reflexed and adnate to the stipe at certain points, up to 5 cm. in diam. ; hymenium dark brown or black ; stipe deeply fluted, up to 10 cm. long and 3 cm. thick, yellowish ; spores ellipsoid, smooth, hyaline, 18-20 x 10-12 μ.

On the ground, Murree, Patriata, Nathia Gali, Kagan Valley, Swat State. · Very common everywhere in the hills.

2. **Helvella crispa** Scop. ex Fr. *Syst. Myc.* 2 : 14, 1822.

*H. crispa*. Ascocarp, x 1

*H. elastica*. Ascocarp, x 1

Pileus mitrate or saddle-shaped, reflexed and usually irregularly lobed, up to 4 cm. in diam. ; hymenium white or cream coloured ; stipe deeply fluted, up to 7 cm. long and 3 cm. thick, white ; spores ellipsoid, hyaline, smooth, 18-20 x 10-12 $\mu$.

On the ground, Murree, Patriata, Shogran, Kalam. Very common.

3. **Helvella elastica** Bull. ex Fr. *Syst. Myc.* 2 : 21, 1822.

Pileus irregularly saddle-shaped, margin reflexed, up to 3 cm in diam ; hymenium yellowish to dark brown or nearly black ; stipe up to 10 cm. long and 2 cm. thick, even, yellowish ; spores ellipsoid, hyaline, smooth, 18-20 x 9-11 $\mu$.

On the ground, Murree, Shogran, Swat State. Very common.

4. **Helvella ephippium** Lev. *Ann. Sci. Nat.* ser. 2, 16 : 240, 1841.

Pileus at first discoid then saddle-shaped, margin reflexed, up to 1.5 cm. in diam., lower surface tomentose, brownish ; hymenium smooth, brown ; stipe cylindric, pale grey, hairy, hollow, up to 5 cm. long and 1.5 mm. thick ; spores elliptic, hyaline, smooth, 16-18 x 9-11 μ.

On the ground, Murree, Patriata, Charehan, Kagan valley, Swat State. Common everywhere.

*H. ephippium.*
Ascocarp, x 1

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# A New Termite from East Pakistan (Isoptera, Termitidae)

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This paper is based on the material sent to me for determination by Dr Ghulamullah, Forest Entomologist, Pakistan Forest Research Institute, Abbottabad. It describes a new species of termite from East Pakistan. The holotype and one paratype are in the author's collection, and two paratypes are deposited in the Emerson Collection of the American Museum of Natural History, New York.

I am greatly indebted to Professor Alfred E. Emerson of the University of Chicago for kindly confirming the identification. My thanks are also due to Dr Ghulamullah for providing the material.

## *Microtermes pakistanicus* n. sp.

SOLDIER (Figure 1 and Table I) : Head antennae and pronotum yellowish; labrum and postclypeus slightly darker than the head; mandibles brownish yellow at the base, reddish brown in outer three-fourths. Head with a few scattered bristles; labrum with bristles arranged in two vertical rows, anterior bristles longer than posterior bristles; pronotum with a few short hairs along the antero-lateral margins, two long bristles on each lateral lobe, rest of pronotum with a few scattered short bristles. Head almost round, nearly as broad as long, only slightly narrowed anteriorly. Mandibles strongly hooked, thin, base broad and thick, outer margin deeply concave in the basal half. Labrum dome-shaped, slightly longer than broad. Anteclypeus trapezoid, anterior margin slightly depressed in the middle, posterior margin concave. Antenna with 15 articles, the second nearly as long as the third and fourth combined, the third slightly shorter than the fourth, the fifth as long as the fourth. Postmentum strongly arched, one-fifth longer than broad. Pronotum saddle-shaped, one-and-a-half times as broad as long, slightly emarginate anteriorly, indistinctly so posteriorly, lateral sides broadly rounded.

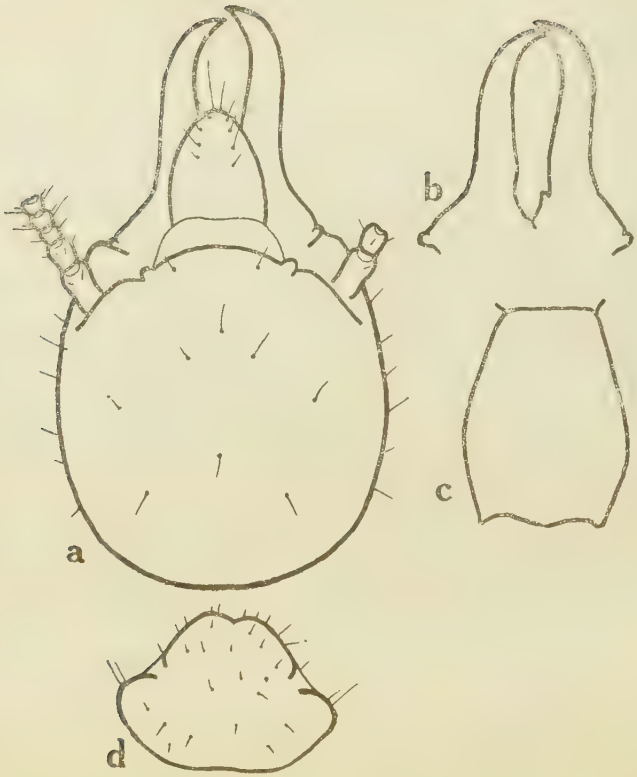


Fig. 1. *Microtermes pakistanicus* n. sp. a, Dorsal view of head. b, Mandibles. c, Postmentum. d, Dorsal view of pronotum. Soldier.

TABLE I

Measurements (in mm.) of the soldier of *Microtermes pakistanicus* n. sp.

| | No. | Range | Mean |
|---|---|---|---|
| Length of head with mandibles | 4 | 1.40-1.51 | 1.46 |
| Length of head to side base of mandibles | 4 | 0.88-0.90 | 0.88 |
| Width of head | 4 | 0.82-0.88 | 0.86 |
| Length of postmentum | 3 | — | 0.53 |
| Width of postmentum | 4 | 0.43-0.49 | 0.45 |
| Length of pronotum | 4 | 0.37-0.40 | 0.38 |
| Width of pronotum | 4 | 0.55-0.61 | 0.58 |

COMPARISONS : Differs from all the species of *Microtermes* hitherto known from India and Pakistan in the almost round head, and strongly hooked mandibles. *Microtermes jacobsoni* Holmgren (from Java, Sumatra, Malacca), *Microtermes pallidus* (Haviland) (from Java, Malacca, Singapore), and *Microtermes insperatus* Kemner (from Java, Malaya) come close to *Microtermes pakistanicus* but have even more strongly hooked mandibles.

TYPE LOCALITY : Mainimukh, Chittagong Hills, East Pakistan, 21. 1. 1954, coll. Ghulamullah. "On bark of teak".

# The Imago of *Kalotermes beesoni* Gardner (Isoptera, Kalotermitidae)

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*Kalotermes*, the most primitive genus of living dry wood termites, belonging to the family Kalotermitidae has a world-wide distribution. According to Emerson (1952) the distribution of its species is : Neotropical region (14), Nearctic region (7), Palaearctic region (6), Ethiopian and Malagasy region (13), Indo-Malaya (7), Australia and Tasmania (10), Papuan region including the South Sea islands (4), and New Zealand (1). In the Indo-Pakistan Sub-continent the genus is represented by a single species, *Kalotermes beesoni*, described by Gardner (1944) from India. Only the soldier caste was described by him. The hitherto unknown imago is described below.

## *Kalotermes beesoni* Gardner

IMAGO (Fig. 1 and Table 1) : Mandibles dark brown ; postclypeus brown ; head reddish brown ; labrum and pronotum slightly lightly coloured than the head ; the proximal articles of antennae and wing veins light brown ; anteclypeus, the terminal articles of antennae, under surface of head, thorax and abdomen yellowish brown ; wing membrane brownish yellow, hyaline ; ocelli whitish. Head with a few scattered short hairs and long bristles ; labrum with bristles on the tip and a few scattered short hairs in the middle ; anteclypeus with a few anteriorly directed hairs on its posterior margin ; pronotum with scattered hairs and bristles ; meso- and metanota scantily hairy. Head broadly oval. Eye large, not quite round, anterior margin straight, separated from lower margin of head by a distance nearly half its long diameter. Ocellus large, oval, touching the eye obliquely. Labrum broader than long, anterior margin convex, posterior margin slightly sinuate, antero-lateral sides broadly rounded. Anteclypeus trapezoid, more than twice as broad as long, anterior margin slightly produced in the middle, posterior margin straight. The left mandible with apical tooth larger than the first marginal tooth ; the latter directed anteriorly, anterior cutting edge almost straight, posterior edge slightly curved ; the second marginal tooth directed posteriorly, anterior cutting edge almost twice as long as posterior cutting edge. The right mandible with the apical tooth only slightly larger than the first marginal tooth ; the second marginal tooth broadly rounded, anterior cutting edge short, posterior edge

greatly elongated. Antenna with 16-18 articles ; in specimens with 17 articles, the second article nearly twice as long as the fourth, the third slightly longer than the fourth. Pronotum broader than long, antero-lateral corners broadly rounded, anterior margin shallowly concave, posterior margin slightly emarginate. Mesonotum much smaller than pronotum, a little broader than long. Metanotum similar to mesonotum but shorter. Scales of forewings large, overlapping the hind wing scales. Forewing with subcosta touching the costal margin at about the basal third of the wing ; radius extending a little beyond the middle of the wing; redius sector with 5-7 branches to the costal margin ; median running about half-way between cubitus and radius sector ; cubitus with variable number of branches.

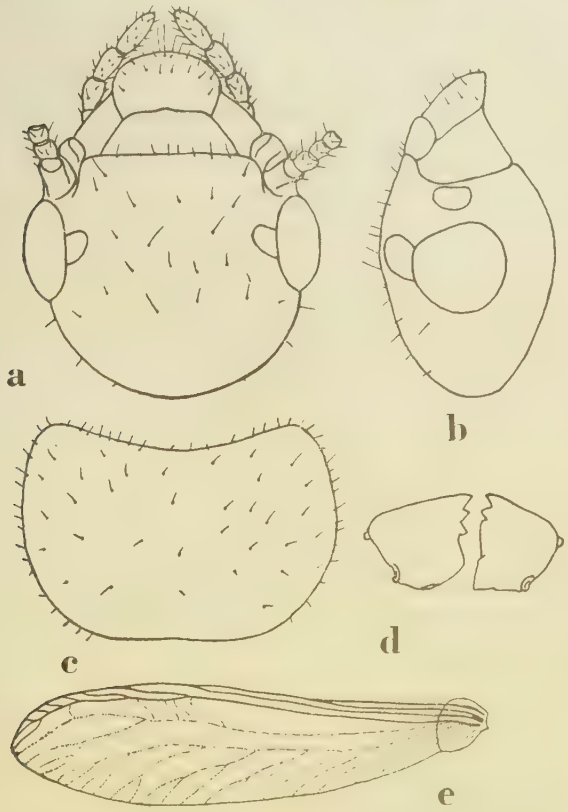


Fig. 1. *Kalotermes beesoni* Gardner. a, Dorsal view of head. b, Lateral view of head. c, Dorsal view of pronotum. d, Mandibles. e, Forewing. Hitherto unknown imago.

TABLE I

Measurements (in Millimeters) of the Imago of *Kalotermes beesoni* Gardner

| | Number | Range | Mean |
|---|---|---|---|
| Length of head to tip of labrum | 16 | 1.51-1.81 | 1.67 |
| Length of head to side base of mandibles | 18 | 1.18-1.56 | 1.31 |
| Width of head across eyes | 19 | 1.36-1.51 | 1.48 |
| Diameter of eye | 19 | 0.48-0.59 | 0.52 |
| Length of ocellus | 19 | 0.18-0.25 | 0.22 |
| Width of ocellus | 19 | 0.14-0.20 | 0.16 |
| Length of pronotum | 19 | 0.68-0.79 | 0.73 |
| Width of pronotum | 19 | 1.55-1.66 | 1.59 |

COMPARISONS : Differs from *Kalotermes indicus* Holmgren (from Makassar, Celebes) and *Kalotermes mcgregori* Light (from Philippines) in having pronotum only slightly wider than head (difference between width of head and width of pronotum is 0.47 mm. in *K. indicus*; 0.27 mm. in *K. mcgregori;* and 0.15 mm. in *K. beesoni).* Comes close to *Kalotermes jepsoni* Kemner, and *Kalotermes pintoi* Kemner, both from Ceylon, in having pronotum only slightly broader than head, but differs from both in having distinctly broader head and pronotum.

DISTRIBUTION : Haldwani, United Provinces, India, soldiers and nymphs, coll. C.F.C. Beeson. Lahore, Punjab, West Pakistan, imagoes, soldiers and nymphs, coll. M. A. Khan and M. Ahmad, 10. VII. 1952. Mianwali, Punjab, West Pakistan, soldiers and nymphs, coll. N. A. Bashir, 10. XI. 1954.

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# A New Spirurid (Nematoda : Acuariidae) from a Hornbill *

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Some nematode worms were collected by Dr Abdussalam, Professor of Pathology, Punjab College of Animal Husbandry, Lahore, from the stomach of a hornbill, *Tockus birostris* Scopoli, which died in the Zoological Gardens, Lahore. The collection contained seven females (five complete and two injured) and two males (one injured and one broken) of a species belonging to the genus *Dispharynx* Railliet, Henry and Sisoff in the family Acuariidae. As they differ in certain important characters from the known species of the genus, they are considered to belong to a new species, for which the name *Dispharynx alata* is proposed.

I am thankful to Dr Abdussalam for giving me an opportunity to examine the worms.

## *Dispharynx alata* n. sp.

DIAGNOSIS : Stout white worms. Cuticular striations fine, about 0.003 mm. apart. Cordons four, wavy, recurrent, extending from lips to about the middle of the first part of oesophagus. Post-cervical papillae tricuspid. Left spicule in the male alate, bidigitate at the apex. Vulva located in the basal fourth of the body.

The worms are stout, white, with bodies coiled into three spiral turns in both sexes.

The *male* measures 4.75 mm. in length and 0.23 mm. in maximum thickness. The transverse striations on the cuticle are 0.003 mm. apart. There are two small, conical lateral lips. The cuticular cordons are wavy, extending behind from the anterior end to 0.30 mm. They are 0.01 mm. wide. The pharynx is thick-walled and measures 0.10 mm. in length. The oesophagus is divided into an anterior muscular part, 0.30 mm. long, and a posterior glandular part, 0.90 mm. in length. The small tricuspid cervical papillae and the nerve ring are situated in front of the posterior limits of the cordons. The papillae are situated between the recurrent branches of the cordons, 0.18 mm. from the anterior end; and the nerve ring 0.12 mm. from the same point. The caudal end of the male is alate, alae being

* This work was done under the I. C. I. grant by the Pakistan Association for the Advancement of Science.

long and relatively wide with transverse striations. The cuticle of the ventral surface in the cloacal region and for some distance in front of it is tessellated. The tail is 0.30 mm. long. There are nine pairs of pedunculate caudal papillae, four pairs preanal, and five pairs postanal. The last pair of postanal papillae is situated a little in front of the tail apex, these papillae being smaller and more shortly pedunculate than other caudal papillae. Spicules unequal and dissimilar. The left spicule is long, slender and alate, its length being 0.36 mm. The apex is blunt, bidigitate and alate. The right spicule is short, boat-shaped, its length being 0.17 mm.

The *female* measures 7.08 mm. in length and 0.48 mm. in maximum width. The cordons extend behind from the anterior end of the body to a distance of 0.64 mm. The pharynx is 0.12 mm. long. The anterior part of the oesophagus is 0.54 mm. long, and the posterior part 1.61 mm. The cervical papillae and the nerve ring are situated 0.48 mm. and 0.13 mm. respectively from the anterior end. The tail is small, bluntly conical and slightly incurved, its length being 0.11 mm. The vulva is situated far behind the middle of the body, 1.25 mm. from the posterior end. The vagina is short, running anteriorly from the vulva. The uterine branches are opposed, and the coils of uterine tubes lie near the opposite ends of the oesophagus, one near the junction of the first and second parts of the oesophagus, and the other near the anus. Eggs measure 0.033-0.036 x 0.019 mm.

COMPARISONS : *Dispharynx alata* differs from other described species of the genus in the alate left spicule with its apex not pointed but bidigitate. It comes close to *Dispharynx nastua* (Rud.) and *Dispharynx papilonis* Olsen in having (a) cuticular cordons not so much sinuate as in other species of the genus, (b) five pairs of postanal papillae in the male, and (c) vulva further behind the middle of the body ; but differs in the cuticular cordons extending behind up to the middle of the first part of the oesophagus, tricuspid cervical papillae, and alate and bidigitate left spicule.

HOST : Hornbill, *Tochus birostris.*

LOCATION : Stomach.

LOCALITY : Lahore, Punjab.

TYPE SPECIMENS : Deposited in the Museum of the Zoological Survey of Pakistan, Karachi.

*Dispharynx alata* n. sp.

Fig. 1, Anterior extremity of male, dorso-lateral view; Fig. 2, Cuticular Cordon; Fig. 3, Cervical papillae; Fig. 4, Posterior end of male, lateral view; Fig. 5, Apex of left spicule; Fig. 6, Posterior end of female, lateral view; Fig. 7, Eggs.

# Two New Genera of Hypermastigote Flagellates from the Termite *Archotermopsis wroughtoni* (Desneux)

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The intestinal flagellates of *Archotermopsis wroughtoni* (Desneux), a termite commonly distributed in the lower level coniferous forests of North Western Himalayas, were first studied by Imms (1920). He recognized five species in all. Of these, two species were named by him as *Trichonympha (Holomastigotoides) pristina*, and *Trichomonas termitis*, and the third was identified as *Treponema termitis* Leidy. The remaining two species ware only partially described under the designation species ∝ and species β.

Cutler (1920) made a detailed study of the flagellates grouped under species ∝ and β by Imms. He recognized two species among the flagellates previously referred to as species β and created the genus *Joenopsis* for these two species which he named as *Joenopsis polytricha* and *Joenopsis cephalotricha*, the former being the generitype.

Cutler (1921) gave a detailed description of Imms's *Trichonympha (Holomastigotoides) pristina* under the designation *Pseudotrichonympha pristina* (Imms). Mello (1920, *a*) reported that this flagellate was identical with *Trichonympha agilis* which he (1920) had described from *Heterotermes (=Leucotermes) indicola* (Wasmann). In 1927 he, however, mentioned it as *Pseudotrichonympha pristina* (Imms) in his list of the then known species of *Pseudotrichonympha*.

Recently, a detailed study of the flagellates of Protozoa-harbouring termites of the Punjab was undertaken and the intestinal protozoa of *Archotermopsis wroughtoni* re-examined. The present study reveals that it is not justifiable to assign the flagellates *Trichonympha pristina* and *Joenopsis cephalotricha* to the genera *Trichonympha* and *Joenopsis* respectively. Consequently, two new genera, viz., *Prototrichonympha* and *Parajoenopsis* have been proposed to accommodate these flagellates.

Smears were made from specimens of *A. wroughtoni* collected from the Murree Hills forests of the Punjab. They were fixed in Bouin's and Schaudinn's fixatives and stained with Heidenhain's Iron haematoxylin.

I am greatly indebted to Dr Muzaffer Ahmad of the Zoology Department, University of the Punjab, for suggesting the problem and taking keen interest in the progress of the work.

## Family TRICHONYMPHIDAE

### *Prototrichonympha* gen. nov.

GENERITYPE : *Trichonympha (Holomastigotoides) pristina* Imms

(Fig. 1, *a* & *b*)

DIAGNOSIS : Body spindle-shaped to oval ; rostrum simple, devoid of head-cap, the apical round body and the rostral tube; no deeply staining ectoplasmic sheath round the rostrum : anterior part of the body not differentiated into inner and outer layers of ectoplasm ; posterior tip of the body without flagella ; two wavy protoplasmic threads joining the nucleus with the rostrum ; a bundle of protoplasmic threads, the axostyle, running from the nucleus towards the posterior end of the body ; nucleus usually oval, rarely rounded, situated in the anterior part of the body ; length of the body 151.3 $\mu$ (116.6-208.2 $\mu$), breadth of the body 54.6 $\mu$ (33.3-83.3 $\mu$) ; long diameter of the nucleus 21.7 $\mu$ (16-24 $\mu$), short diameter of the nucleus 17.6 $\mu$ (16-20 $\mu$) ; length of the rostrum 7.6 $\mu$ (7.2-18.6$\mu$), width of the rostrum 3.6$\mu$ (2.7-5.4 $\mu$).

*Prototrichonympha pristina* is the largest of all the flagellates found in the hind gut of *Archotermopsis wroughtoni* (Desneux). In both the living and fixed preparations, the general shape of the body is spindle-like, but oval forms are also found in the same preparation. With the exception of the posterior tip, the whole body is covered over by flagella. There is no differentiation of protoplasm into ecto-and endoplasm, even in the anterior region of the body where the protoplasm is clearer than in the rest of the body. Imms (1920), however, states that in somewhat contracted specimens there appears to be an outer hyaline layer, surrounding a dense inner mass, suggesting a differentiation into ecto-and endosarc, but this, according to him, is an artifact produced by the physical reaction of the reagents.

The anterior end of the body is modified into a rostrum which forms a characteristic feature of the family Trichonymphidae. It is separated from the body proper by a notch. It is much simpler in structure than the rostrum of all the known genera of the family Trichonymphidae. Imms (1920), described it as consisting of a minute cuticular cylinder closed anteriorly by a cap and enclosing a stainable blepharoplast. Mello (1920), reported that it was comparable with the rostrum of *Trichonympha agilis* found in the intestine of *Heterotermes indicola*. Cutler (1921) described it as composed of two portions, an inner tube completely covered by an ectoplasmic sheath, continuous with the rest of the body. My

observations are that due to the arrangement of basal granules in two vertical lines, the rostrum looks like consisting of a central tube surrounded by an outer layer of ectoplasm. The basal granules are so close to each other that it is only in very good preparations that they are seen distinctly. This probably led Cutler to think that there is an outer ectoplasmic sheath in the rostrum. Further, there is no such structure as the head-cap covering the rostrum, as described by Imms (1920). The appearance of the head-cap might be due to an artifact, when only the apical part of the rostrum is stained. Cutler (1921) also has not observed any cap covering the rostrum. The length of the flagella of the rostrum or the head flagella varies from 8 μ to 20 μ. They are slightly longer than the body flagella.

The body proper, except the posterior tip, is covered all over by flagella. The length of the flagella varies from 8 μ to 16 μ. The flagellar bands run longitudinally over the surface of the body.

Nucleus is situated a little anterior to the centre of the body. It is usually ovoid but in some specimens it is rounded. The well-developed nuclear membrane is separated from the chromatin mass which lies in the centre of the nucleus.

In some good preparations are seen two thread like structures running posteriorly from the tip of the rostrum. After coming out of the rostrum they take a rather wavy course in the body proper, before joining the nuclear membrane. The protoplasm enclosed by these threads takes a deeper stain than the surrounding protoplasm.

To the posterior side of the nucleus is attached a bundle of protoplasmic threads, the axostyle (not described by earlier authors), which extends up to the posterior end of the body. It tapers gradually towards the posterior end. Anteriorly a few fibres of the axostyle cover the nucleus on all sides and appear to be continuous with the two threads coming from the anterior end of the rostrum to join the nuclear membrane.

The genus *Prototrichonympha* has a much simpler rostrum as compared to the other members of the family Trichonymphidae. The rostrum is devoid of the sheath, the rostral tube, the round body and the headcap. The anterior part of the body is not differentiated into ectoplasm and endoplasm. The genus *Pseudotrichonympha* Grassi, to which this flagellate was originally referred, has a rostrum with a definite rostral tube, having round body at its top, covered over by a head-cap (Fig. 2). The anterior part of the body is differentiated into ecto-and endoplasm. The ectoplasm is further divided into a narrow inner and a wider outer layer, of which the

latter only surrounds the rostrum. In the allied genus *Trichonympha* Leidy, both the inner and outer layers of ectoplasm surround the rostrum, while *Deltotrichonympha* Sutherland has a much more complicated rostrum.

## Family LOPHOMONADIDAE

### *Parajoenopsis* gen. nov.

GENERITYPE : *Joenopsis cephalotricha* Cutler

(Fig. 3)

DIAGNOSIS : Body pyriform ; oblique groove and parabasal body absent ; flagella confined to the head region ; horseshoe-shaped supporting body in front of the nucleus present ; striations from the supporting body short, not extending beyond the anterior third of the body, devoid of basal granules ; length 55.1 $\mu$ (46-75 $\mu$) ; width 28.5 $\mu$ (26-40 $\mu$) ; diameter of the nucleus 5.6 $\mu$ (4-8 $\mu$).

*Parajoenopsis cephalotricha* has a pyriform body, the anterior end of which is more broadly rounded than the posterior end. The oblique groove, which is so characteristic of *Joenopsis polytricha* Cutler, is absent in this flagellate. As in *J. polytricha*, a horseshoe-shaped supporting body is present near the anterior end of the body. Head flagella whose length varies from 12 $\mu$ to 20 $\mu$, take their origin from the basal granules present on each limb of the supporting body. The parabasal body which is very well-developed in *J. polytricha* is completely missing. Striations radiating from the supporting body do not extend beyond the anterior third of the body. These are present all round the body and are devoid of basal granules and consequently the body flagella are also absent. Axostyle pierces through the posterior end of the body. The posterior end of the axostyle is pointed. The nucleus is broadly oval and situated between the two limbs of the supporting body. The nuclear membrane is very distinct and the chromatin mass lies in the centre of the nucleus.

The new genus *Parajoenopsis* is proposed for Culter's *Joenopsis cephalotricha*. The differences between this species and *J. polytricha* are great enough to warrant its (*J. cephalotricha*) separation from the present genus and assigning it to a new genus. Cutler (1920), while comparing *Joenopsis* with *Joenia* says that "probably, however, the most characteristic feature common to the two genera is the well-developed parabasal apparatus, consisting of parabasal threads to which the parabasal bodies (figlioline) are attached, the whole complex in *J. polytricha* strongly recalling the description given by Grassi of the 'regolo', 'collare' and 'figlioline'." He further says that "turning to other characters which separate *Joenopsis* from *Joenia*, its neighbouring genus, there may be mentioned the

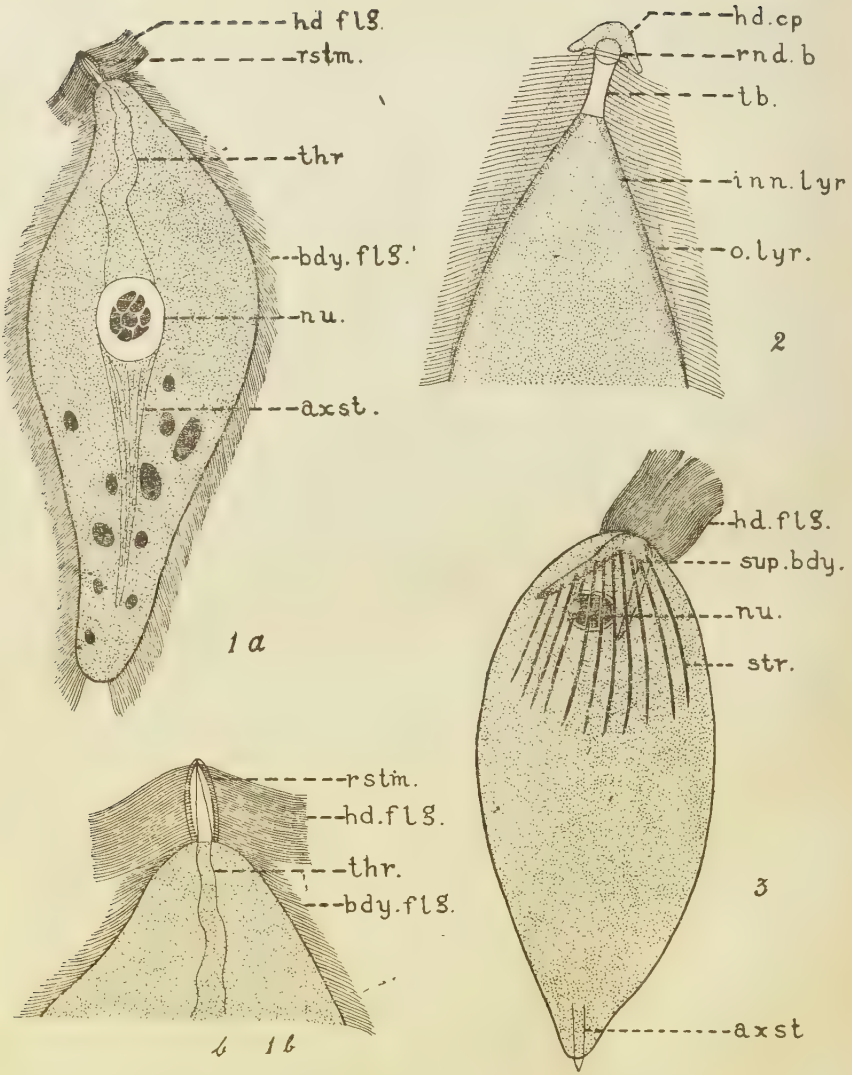


Fig. 1. *Prototrichonympha pristina* (Imms). (a), entire individual (x 580) (b), anterior third of the body greatly enlarged (x 1180). axst., axostyle ; bd. flg., body flagella ; nu., nuleus ; rstm., rostrum ; thr., thread.

Fig. 2. *Pseudotrichonympha grassi* Koizumi from *Coptotermes heimi* (Wasmann) : Anterior third of the body greatly enlarged (x 1180). hd. cp., head-cap ; inn. lyr., inner layer of ectoplasm ; o.lyr., outer layer of ectoplasm ; rnd. b., round body ; tb., rostral tube.

Fig. 3. *Parajoenopsis cephalotricha* (Cutler). Entire individual (x 1180). hd. flg. head flagella ; nu., nucleus ; str., striations ; sup. bdy., supporting body.

groove of the body. Of greater interest, however, are the longitudinal striations, with their attendant flagella." It would thus appear that according to Cutler the three diagnostic features of the genus *Joenopsis* are (i), parabasal apparatus ; (ii), oblique groove of the body and (iii), body flagella arranged in longitudinal rows. None of these characters is present in *Parajoenopsis*.

*Parajoenopsis* comes nearest to *Joenopsis* in having (1), a horseshoe-shaped supporting body ; (2), a tuft of flagella in the head region ; (3), homogeneous mass of protoplasm in the anterior region of the body.

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# The Genus *Retortamonas* Grassi

(Mastigophora : Retortamonidae)

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## INTRODUCTION

The genus *Retortamonas* Grassi 1879 has attracted the attention of several eminent protozoologists. The synonymy of this genus has, till recently, been in a state of confusion owing to an inadequate original description. Difficulties inherent in the study of morphology, together with a lack of knowledge of the biology of the organisms, were mainly responsible for this inadequacy.

The confusion of synonymy was brought home to the present author while he was trying to indentify a flagellate obtained from *Gryllotalpa africana* Linn. Consequently, a detailed investigation of the genus has been undertaken and the results presented in the following pages. In all 21 species, of which one is new, have been described in detail, and the recent views on the taxonomy of the genus discussed at length.

This work was done in the Institute of Parasitology, Faculty of Medicine, Paris. I consider it a privilege to express my gratitude to Professor H. Galliard and Professor I. C. Brumpt for facilities, guidance and encouragement during the course of this work. I desire to place on record my sense of obligation to Professor M. Afzal Husain, who impressed upon me the importance of Protozoology. My thanks are also due to Dr Abdus Salam of the Punjab College of Animal Husbandry, Lahore, for going through the manuscript and giving me the benefit of his opinion.

## HISTORICAL

In 1879, Grassi created the genus *Monocercomonas* to accommodate a very heterogeneous assemblage of flagellates, and split it up into four subgenera, viz., *Monocercomonas, Schedocercomonas, Trichomonas* and *Retortamonas*. The subgenus *Retortamonas* was based on a flagellate obtained from *Gryllotalpa gryllotalpa* Linn. This flagellate was given the

specific name of *Retortamonas gryllotalpae* and was described very briefly, without any illustrations. In 1881, he described this flagellate in detail, giving two illustrations, but for no apparent reason altering the name to *Plagiomonas grillotalpae.*

Doflein (1901) assigned *Plagiomonas grillotalpae* to the genus *Bodo*, but several workers have since demonstrated this conclusion to be erroneous. Stiles (1902) critically reviewed Grassi's genera of 1879 and 1881, and showed for the first time that *Plagiomonas* was merely a synonym of *Retortamonas*.

The genus *Embadomonas* was created by Mackinnon (1911) for a flagellate obtained from trichopterous larvae and named *E. agilis*. Several other species were later added to the genus by Mackinnon and other workers.

Wenyon & O'Connor (1917) created a new genus *Waskia* to accommodate a small flagellate discovered in two patients in Alexandria. Chalmers & Pekkola (1918) reduced this genus to a synonym of *Embadomonas*. Wenrich (1931) extensively studied a small flagellate found in *Gryllotalpa gryllotalpa*. He also studied various species of *Embadomonas* and concluded that all these forms were cogeneric. He further identified the *Gryllotalpa* flagellate as *Retortamonas gryllotalpae*. These conclusions were not accepted by Bishop (1934) and Dobell (1935). The objections were that (i) the figures and description of *Plagiomonas grillotalpae* given by Grassi in 1881 did not sufficiently resemble *Embadomonas* spp., and (ii) Grassi (1888) characterized *Plagiomonas* as having three flagella whereas *Embadomonas* had only two. A reference to Grassi (1879, 1888) will show that he actually aggravated the confusion by recording uncertain information regarding the structure of the organism and the number of flagella.

Corradetti (1937), and Kirby & Honigberg (1950), on the other hand, strongly supported the views advanced by Wenrich. They stated that the description of *R. gryllotalpae* Grassi given by Wenrich, and of *E. agilis* by Mackinnon (1911), are very similar and one cannot escape the conclusion that the two belong to the same genus. They added that there could be two possibilties. Either *G. gryllotalpa* harbours both *Retortamonas* and *Embadomonas* or the flagellate encountered by Wenrich was *Retortamonas*.

Wenrich (1932) and Corradetti (1937) recorded three distinct species from *Gryllotalpa gryllotalpa*, viz., *Hexamastrix gryllotalpae* Grassi

(1926), *Schedocercomonas (Monocercomonoides) gryllotalpae* Grassi (1879), and *Retortamonas gryllotalpae* Grassi (1879).

The brief description of *Retortamonas gryllotalpae* by Grassi in 1879 and a detailed account with illustration in 1881 convince one of the similarity of *Retortamonas* and *Embadomonas*. The figure represents the following characteristics : Hyaline anterolateral area, two laterel flagella (one directed anteriorly and the other posteriorly), caudal extremity gradually narrowed. All these characters are the same as described by Wenrich.

In 1888, while defining *Plagiomonas*, Grassi mentioned two anterior and one posterior flagella. Kirby & Honigberg (1950) pointed out that there is no posterior flagellum in the group to which *Retortamonas (Plagiomonas)* belongs. In an allied species *R. wenrichi* Stabler 1924, from *Gryllotalpa hexadactyla*, the caudal process is filamentous and is several times longer than the body. Corradetti (1937) stated that Grassi had mistaken the caudal process for a posterior flagellum. He has further added that whereas the description and illustrations given by Grassi in 1881 are more authentic, the description given in 1888 is brief, not based on any further studies of the material, and therefore not reliable.

From the above account it is evident that *Retortamonas* Grassi (1879) is the valid name on the basis of priority. The various other names discussed above have consequently been reduced to its synonyms : *Monocercomonas* Grassi 1879, *Plagiomonas* Grassi 1881, *Bodo* Doflein 1901, *Embadomonas* Mackinnon 1911, *Waskia* Wenyon & O'Connor 1917, and *Retortamonas* Prowazek 1931.

## MORPHOLOGY

*Trophozoites* : The trophozoites are pyriform in dorsal and ventral view, broadest in the middle. The anterior end is blunt and is usually bent back at some part in the anterior half at a considerable angle to the long axis. This inclination subjects the cytostome to face almost straight. Posteriorly the body tapers gently to form the caudal area. The caudal end is blunt and in some species it is pulled out considerably to form a long tail. Intermediate conditions are quite frequent.

Body is covered with a definite periplast. The pellicle varies considerably from one species to another, and is mostly delicate and pliable, not permitting amoeboid movements.

Internal structures consist of one spherical nucleus in the anterior

area, cytostome, peristomal fibre around cytostome, neuromotor apparatus and two flagella.

*Nucleus* is the most striking object, large, spherical and vesicular, situated in the anterior region. Nuclear membrane usually not well differentiated. The *karyosome* is central and large in individuals not preparing for division and encystation. It consists of a single granule or of several granules grouped together to form an irregular mass on a faint network. There is a clear and hyaline space called *halo* below the nuclear wall and central karyosome. A layer of chromatin immediately inside nuclear membrane is always present. It is more concentrated in some cases while in others it is thin and is therefore not easily differentiated. In some individuals peripheral chromatin is regularly distinct, while in others it is concentrated in a rod- or crescent-shaped mass at one pole. The *blepharoplasts* are two, small, spherical and briefly refractive chromatinic granules situated anterior or anterolateral to the nucleus. Both granules are closely applied to the nuclear membrane. One lies towards the anterior pole of the nucleus while the other is at the anterior end of the cytostome. Each blepharoplast gives rise to the respective flagella. The central rounded ovoid karyosome is conneted to centrosome on the nuclear membrane by a rhizoplast. The centrosome in turn is linked to the blepharoplasts by a small extra-nuclear rhizoplast. This integrated system is the neuromotor system of the parasites. There are two *flagella*, arising close together from the basal granules on the edge of the nuclear membrane (blepharoplast). The first is directed anteriorly and is the chief organ of propulsion. It describes a wide spherical movement responsible for the forward movement. The other is the trailing flagellum and is completely confined to the oral pouch in some species while in others it projects laterally or from the posterior end of the depression. It moves in an undulating manner and is, therefore, visible as a sinuous structure in slide preparations. It assists the organisms in the capture of the food and gives an additional aid in the lateral movements. The sum total of these forward and lateral forces produce peculiar jerky movements. The side movements are controlled by the cytostome. The length and thickness of the two flagella vary considerably from one species to another. The *cytostome* is situated externally to the nucleus. It extends from the anterior end to a point about one-fourth to one-half way or even more along the body. It is deepest anteriorly and lies on the ventral side of the nucleus. The margins of the oral pouch show well defined siderophilous lips which may be wavy or slightly undulating. The supporting fibrils extend round the anterior end of the depression and along

the two sides, and form more or less a u-shaped curve. The posterior side appears to be devoid of siderophilous fibrils. The food is taken in at a point a little below the anterior edge. The cytostome is highly vacuolated and crowded with masses of bacteria ingested by the organism.

*Precystic forms :* The precystic forms are spherical. Anterior flagella remain free. The border of the cytostome is distinct. Recurrent flagellum is maintained in oral pouch. Basal granules are distinct. Food inclusions are sparse or wanting entirely.

*Newly formed cysts :* In young cysts the nucleus maintains its original position, form and structure. In advanced stages, however, the chromatin granules predominate in the anterior pole alone. Border of the cytostome is visible as loop-shaped strands and the periplast of the flagellate is retained adjacent to the cyst wall.

*Mature cysts :* Fully formed cysts are minute, pear-shaped or ovate hyaline bodies, with indistinctly differentiated internal structures. Cytoplasm is finely granular, almost homogeneous. Nucleus is visible as a spherical object on the superior pole, showing a variety of structures according to the stage of development. Basal granules are sometimes detected easily. The border of the cytostome persists as a twisted or looped fibril in the centre of the cyst. Anterior flagella are coiled round and lie immediately below tne cyst wall and appear as a siderophilous fibre. Cyst wall is distinct. Pellicle of the trophozoites is retained adjacent to the cyst wall.

### DIAGNOSIS OF THE GENUS

The flagellates belonging to this genus small, elongate or pyriform, anteriorly rounded and posteriorly pointed, resembling a slipper. Cytostomal depression anterolateral, comparatively large with prominent chromophilic lips. There are two flagella arising from separate blepharoplasts situated at the anterior border of the cytostome. One of the flagella directed anteriorly and the other posteriorly, the latter originating from a granule near the anterior margin of the cytostome and characteristically trailing within its cavity. Nucleus spherical, situated anteriorly, and with a large karyosome. Parabasal bodies and axostyle wanting. Contractile vacuoles distinct. Caudal end sometime drawn out to form a filamentous tail. Ventral profile convex while the dorsal profile straight.

HOSTS : Species of *Retortamonas* have been recorded from various insects, amphibians, reptiles and mammals (Table II).

HABITAT : Alimentary canal of the host.

GENERITYPE : *Retortamonas gryllotalpae* Grassi 1879, ex- *Gryllotalpa gryllotalpa* Linn.

Much of the literature on *Retortamonas* is purely systematic in character. These flagellates infest both vertebrates and invertebrates and have been reported from 5 rodents, 3 primates, 2 ungulates, 1 edentate, 1 marsupial, 1 reptile, 8 amphibians and 10 insects. Various species are differentiated mainly on the bases of size, shape of the trophozoites and cysts, the relative length and stoutness of the flagella, and the characteristics of the cytostome. Host difference is also an important consideration in the concept of the species. With the exception of *R. wenrichi* Stabler, *R. caudacus* Geimann and *R. gryllotalpae* Grassi, which are furnished with a characteristic caudal process, the species of *Retortamonas* are very similar in appearance. The morphological characters are too inconsistent to be employed in any workable key. The following key is purely for preliminary identification and a reference is indispensable to the detailed description of the species.

KEY TO THE SPECIES

1 (6) Trophozoites with a long tapering or filamentous caudal pocress.

2 (5) Caudal process about 1/3 to 2/5 the body length. Cysts ovate and without a deeply stained pad on poles.

3 (4) Anterior flagellum as long as or even longer than the body. Posterior flagellum almost half of its length. Oral pouch approximately one-half as long as the trunk of the flagellate. Body cylindrical. Cysts ovate, with structures other than nucleus indistinct ..... *Retortamonas caudacus*

4 (3) Both the flagella usually about one-third as long as the body. Body spindle-shaped. Cysts ovate, with the various structures distinct ..... *Retortamonas gryllotalpae*

5 (2) Caudal process equal to or about three times as long as the body. Cysts ovate with a distinct, deeply stained pad at the anterior pole..... *Retortamonas wenrichi*

6 (1) Trophozoite without a long tapering filamentous tail, caudal end rounded or slightly angulate with a minute spikelet in some species.

7 (16) Anterior flagellum longer than the recurrent flagellum which is short and mostly confined to the oral pouch.

8 (15) Anterior end of the body bent backwards at a slight angle, not pulled out.

9 (14) Cytostome large, confined to the anterolateral half of the body. Siderophilous lips well developed.

10 (13) Nucleus spherical, well developed, with chromatin granules often massed in the centre; and peripheral chromatin often in crescent-shaped mass at one side. Body robust. Peristomal ridge wavy.

11 (12) Cytostome comparatively broader, almost spread to more than half across the width. Periplast delicate, body twisted ..... ..... *Retortamonas phyllophagae*

12 (11) Cytostome narrow, cylindrical, occupying about one-fouth of the surface across the width; pellicle rigid, body not twisted..... ..... *Retortamonas alexeiffi*

13 (10) Nucleus feebly developed, poor in chromatin with thin peripheral layer, and more or less well developed karyosome ..... ..... *Retortamonas blattae*

14 (9) Cytostome confined to the anterior quarter of the body, narrow, with feeble but rigid siderophilous border ..... .... ..... *Retortamonas cuniculi*

15 (8) Anterior end of the body cylindrical, very flexible, and bent back at a considerable angle to the long axis of the body so as to change the direction of the cytostome to frontolateral..... ..... *Retortamonas agilis*

16 (7) Both the free and antero-cytostomic flagella long.

17 (26) Cytostomal depression narrow, ovate; gullet extending posteriorly for about a quarter or one third of the body length.

18 (25) Both the flagella at least as long as the body of the organism.

19 (22) Nucleus very large in size. Interior nuclear ring with continuous ring of chromatinic granules. Karyosome large.

20 (21) Flagella almost twice as long as the body of the flagellate ..... ..... *Retortamonas termitis*

21 (20) Flagella as long as the body of the flagellate..... ..... *Retortamonas mitrulae*

22 (19) Nucleus feebly developed, poor in chromatin, peripheral layer thin.

23 (24) Body 12.0—19.0 μ long and more or less half this much in width ..... *Retortamonas testudae*

24 (23) Body as long as 6.5—9.0 μ (7.9 μ) and 2.0—4.0 μ (3.1 μ) in width ..... *Retortamonas ruminatum*

25 (18) Flagella approximately half as long as the body. Trophozoites square in appearance, measuring 14.0—12.0 μ ..... ..... *Retortamonas wenyoni*

26 (17) Cytostomal depression large and extending posteriorly to about one half of the body length.

27 (36) Nucleus well developed, vesicular and large.

28 (35) Nucleus with distinct karyosome.

29 (30) Flagella considerably larger than the body. Shape of the body elongately ovoid with caudal angulation ..... .....*Retortamonas intestinalis*

30 (29) Flagella never longer than the body.

31 (34) Body length more or less twice the width of the organism.

32 (33) Cytostome at least twice as wide as in the species given below. Sides of the body sloping rapidly and with a concavity beyond the middle ..... *Retortamonas caviae.*

33 (32) Cytostome narrow and cylindrical. Body cylindrical, with a steady and sloping convexity beyond the middle ..... ... ..... *Retortamonas bradypi*

34 (31) Body length not more than 1.5 times the breadth of the organism. Body plump, egg-shaped..... *Retortamonas ovis*

35 (28) Nucleus without a distinct karyosome in the resting stage..... .....*Retortamonas dobelli*

36 (27) Nucleus not enormous, almost half the size found in above species.

37 (38) Nucleus lies conspicuously away from the anterior margin of the cytostome. Cytostome pouch-like and originating a little away from the frontal margin ..... *Retortamonas sinensis*

38 (37) Nucleus lies between the frontal margin of the body and the anterior margin of the cytostome, leaving no space around as seen in the above species. Cytostome cylindrical and originating from tne extreme anterior margin of the body ..... ..... *Retortamonas belostomae*

### *1. Retortamonas agilis* (Mackinnon)

(Figs. 27-29)

*Embadomonas agilis* Mackinnon, 1911, *Parasitology*, 4 : 28-37

Trophozoites slender, slipper-shaped, broadest between the middle and tail end, measuring from 8.0 to 14.0 μ with an average of 9.5 μ in length and from 1.5 to 4.5 μ with an average of 2.0 μ in greatest width. Anterior end rounded and bent back to form the heel of the slipper. Posterior end sharply pointed. Cytostome large, occupying almost four-fifths of the antero-lateral half. Siderophilous borders feebly developed. Posterior border produced into a lip. Anteriorly directed flagellum slender and long, three-fourths of the body length, mainly functioning as the chief organ of propulsion. Posterior flagellum within oral pouch, delicate, inconspicuous and may often be concealed ; in some specimens its end projecting laterally from the cytostome and modified to assist in the capture of the food. Nucleus occupying all the anterior region above the cytostome, spherical and vesicular ; nuclear membrane not well differentiated. Blepharoplasts two blackish dots lying on the anterior pole of the nucleus, from which two flagella originate.

Cysts are minute, ovate, hyaline bodies surrounded by a distinct cyst-wall which is more refractive than the remainder of cyst, measuring 3.5 to 4.0 μ in the greatest axis and 3.0 μ in width. It is extremely difficult to make out any internal structures. A group of chromatin granules near the anterior pole and a dark hooked fibre in the position of cytostome borders are the only structures visible in the finely granular and homogeneous cytoplasm.

This species differs from the type species (*Retortamonas gryllotalpae* Grassi) in the position of the nucleus which occupies the extreme anterior end of the body in contrast to a more posterior position in *R. gryllotalpae* and also in that the flagella are very short, especially the oral flagellum is extremely small and confined to the oral depression. The caudal spike is very small.

HOSTS : Trichopterid larvae and adults, and *Tipula* larvae.

### *2. Retortamonas alexeiffi* (Mackinnon)

(Figs. 18-21)

*Embadomonas alexeiffi* Mackinnon, 1912, *Parasitology*, 5:185-189.

From 5.0 to 9.0 μ with an average of 7.0 μ in greatest breadth. Anterior end round and bent back in some. The posterior end commonly rounded and rarely with attenuated point. Cytostome large with distinct

siderophilous lips. Flagella distinct, posterior one lying within the cytostome, comparatively thicker than the long anterior flagellum and projects some distance beyond the cytostomal edge. Each flagellum arising from a distinct basal granule near the anterior border of the cytostome. Nucleus spherical, always vesicular with distinct membrane, central mass of chromatin granular, peripheral crescent present. Blepharoplast definite, very conspicuous, located near the anterior border of cytostome.

Cysts similar to those of *R. agilis* but proportionately longer, measuring 5-6 μ x 5-5 μ. Nucleus distinct in fresh cysts, but without nuclear membrane, chromatin granules reposed in the anterior pole in older cysts. The looped strands in the position of cytostome border persist in all the cysts.

HOST : *Tipula* sp. larvae.

### 3. *Retortamonas belostomae* (Brug)

(Figs. 55-58)

*Waskia belostomae* Brug, 1922, *Bull. Soc. Path. Exot.*, 15 : 134-139.

Trophozoites leptocephalic in form when seen dorsoventrally and like a silk worm pupa when seen in profile. Anterior end usually rounded, but in some with a minute angulation ; when viewed in profile this portion is found bent back to form something like the head of a bird. Posterior extremities usually pointed but never spiked. Cytostome large, cylindrical with rounded poles, and occupying almost major portion of the anterior half of body. Fibrils lying in the oral margin of more consistent structure. Flagella as long as or slightly longer than the body. Recurrent flagellum traverses a zig-zag patn in the oral pouch before becoming free. Nucleus spherical, situated at the extreme anterior pole of the body. Central karyosome distinct. Blepharoplasts distinctly visible.

Cysts very common, ovoid capsules, measuring 6.0 μ in length and 3.0-4.0 μ in width. The spherical nucleus along with the remains of the flagella reposed in one of the poles. Remains of the oral fibrils coiled up like a loop in the space behind.

Wenyon (1926) did not consider this species to be distinct.

HOST : Diverticulum of *Belostoma* sp.

### 4. *Retortamonas blattae* (Bishop)

(Figs. 22-24)

*Embadomonas blattae* Bishop, 1931, *Parasitology*, 23 : 287-296.

Trophozoites more or less ovoidal in shape. Measuring 6.0-9.0 μ

with an average of 7.0 μ in length and 5.0-7.0 μ with an average of 6.0 μ in width. Anterior end rounded tending to be flexed backwards at some part in the anterior half of the body. Posterior end rounded or terminating in a short spike. Cytostome enormous and occupying almost entire anterolateral half in many individuals. Siderophilous lip of one side slightly more developed than of the other. Flagella usually shorter than the body, arising from closely located minute granules on the edge of nuclear membrane. The flagellum thicker and as long as or even longer than the body. Cytostomal flagellum slender and indistinct, lying mostly in the oral pouch, the tip sometimes projecting slightly from the posterior end of the depression. Nucleus spherical, situated anterolaterally, chromatin rather poor and mostly distributed regularly round the periphery, while in some concentrated at one pole. Karyosome a well defined, central mass of granules. Blepharoplasts minute, basal granules on the edge of nuclear membrane.

Cysts small, pyriform, hyaline, surrounded by a distinct wall, measuring 5.0-6.0 μ long and 4.0-5.0 μ broad. Nucleus of the trophozoites persisting, not appearing to be disintegrating as in *Retortamonas agilis*. Basal granules and the fine cytostomal flagellum distinct in some cysts while indistinguishable in others. Free flagellum lying below the wall as a siderophilous border and frequently crossing the edges of the cytostome. Borders of the cytostome maintained, and in some specimens presenting a twisted appearance.

HOST : The Oriental Cockroach, *Blatta orientalis* Linn.

### 5. *Retortamonas bradypi* (Hegner & Schumaker)
(Figs. 47-48)

*Embadomonas bradypi* Hegner & Schumaker, 1928, *J. Parasitol.*, 15 : 31-37.

Trophozoites slender, ovate, broader anteriorly and narrow post-

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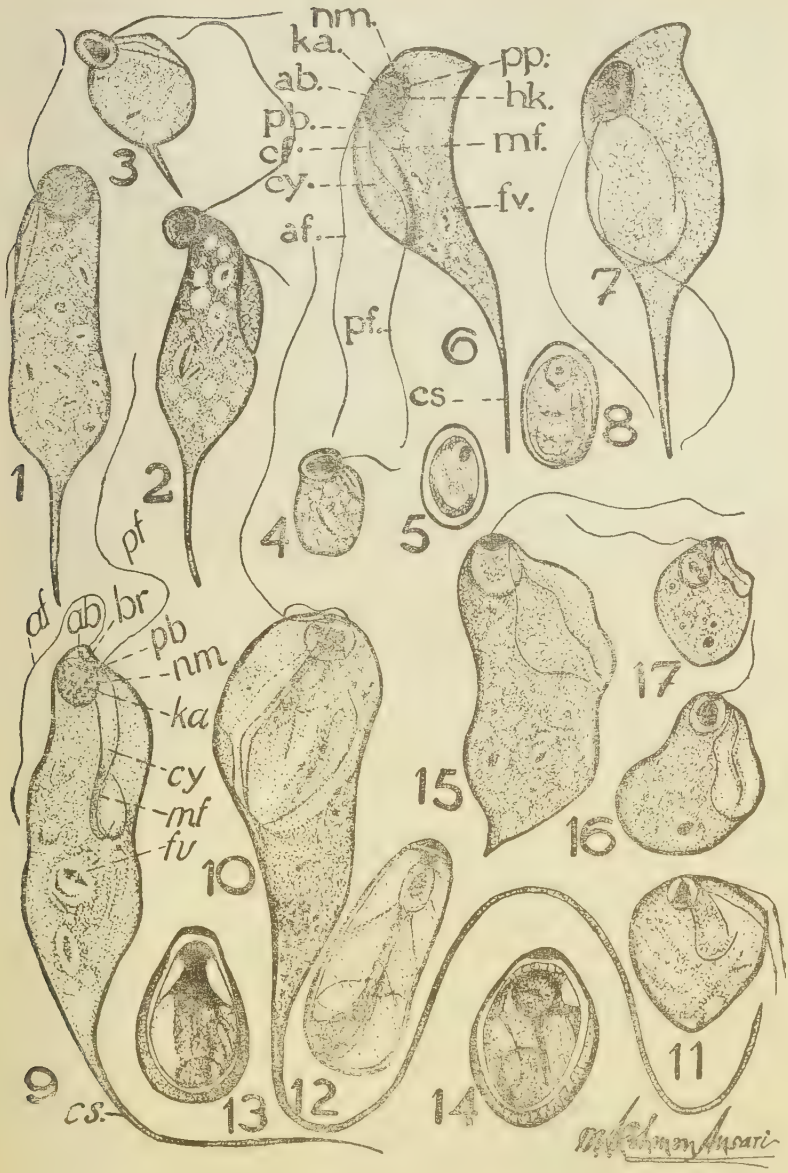
ABBREVIATIONS : *ab* : anterior blepharoplast, *af* : anterior flagellum, *br* : rhizoplast connecting blepharoplasts, *cf* : cytoplasmic part of the posterior flagellum, *cs* : caudal spike, *cy* : Oral pouch or cytostome, *fv* : food vacuole, *hk* : halo round karyosome, *k* : karyosome, *mf* : peristomal fibre, *nm* : nuclear membrane, *pb* : posterior blepharoplast, *pf* : posterior flagellum, *pp* : layer of chromatinic substance.

Figs. 1-5 : *Retortamonas caudacus* Geiman— (1) elongate individual, (2) typical vegetative phase, (3) trophozoite in early phase of cyst formation, (4) precystic stage, and (5) typical cyst. Figs 6-8 : *Retortamonas gryllotalpae* Grassi— (6) lateral view of vegetative form (7) elongate form, and (8) cyst. Figs. 9-14 : *Retortamonas wenrichi* Stabler— (9) typical vegetative form, (10) trophozoites with exceptionally long caudal filament, (11) individual in early stage of encystment, (12) elongate cyst, and (13-14) normal cysts. Figs. 15-17 : *Retortamonas phyllophagae* (Travis & Becker)— (15) vegetative form, and (16-17) young trophozoites.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eriorly, greatest width between the middle of anterior half ; measuring from 4.0-6.5 μ with an average of 4.8 μ and from 6-3.2 μ with an average of 4.24 μ in width. Anterior end broadly rounded, posterior end narrowly rounded. Cytostome narrow, extending almost as long as the body. Recurrent flagellum reaching about half way within the oral pouch, thick. Each flagellum arising from a distinct basal granule, situated near the anterolateral margin of the nuclear wall. Nucleus of usual spherical shape and calls for no comments.

Cysts typical, very slightly longer than broad and therefore appearing more or less rounded. Cyst wall separated from the parasite within by a clear space throughout except the superior pole where the body of the flagellate is in contact. (In this respect it resembles the cysts of *Chilomastix mesnili* Wenyon in reverse order, i. e., the outside contour in *R. bradypi* is what we find in the inside of *C. mesnili* and the inside is what we see in the outside of the same species). Anterior end of the pulled out portion with concentrated cytoplasm to form a pad which stains deeply. Peristomal fibrils and the nucleus present but not distinct. Basal granules and cytostomal flagellum persisting and easily distinguishable. Cysts measuring from 4.3 to 5.5 μ with an average of 4.4 μ in width.

HOST : The three-toed sloth, *Bradypus griseus griseus* Gray, Panama.

### *6. Retortamonas caudacus* Geiman

(Figs. 1-5)

*Retortamonas caudacus* Geiman, 1932, *Trans. Amer. Micr. Soc.*, 51 : 219-224.

Trophozoites with long cylindrical body, gram-pod like in the side view. Anterior pole blunt, showing well marked backward flexure and torsion, posterior extremity extended to form a needle-like tail. Measuring from 6.0-18.0 μ with an average of 10.0-14.0 μ in length and 3.0 to 6.0 μ with an average of 5.0 μ in width. Cytostome enormous, approximately one half as long as the body. Two fibrils, originating from the posterior blepharoplast, border the edge of the oral pouch. Anterior flagella as long as the body of the organism. Posterior flagellum slightly more than half its length. Blepharoplasts situated on the outer margin of the nucleus in the region of the cytostome, distinct only when nuclear chromatin in diffused condition.

Cysts ovate. It is extremely difficult to differentiate structures other than nucleus in the interior of the cyst. In some rare specimens the remains of the flagella as peristomal fibres are dimly visible.

HOST : Aquatic Coleopteran larvae (Gyrinidiae), Massachusetts.

### 7. *Retortamonas caviae* (Hegner & Schumaker)

(Figs. 45-46)

*Embadomonas caviae* Hegner & Schumaker, 1928, *J. Parasitol.*, 15 : 36.

Trophozoites resembling cucumber seed in shape, rounded anteriorly and steadily broadening as far as the middle of the body, whereafter regularly narrowing down to caudal end with a slight lateral concavity. Posterior pole also rounded. Measuring from 4.0 to 7.0 μ with an average of 5.5 μ in length and from 2.0 to 4.0 μ with an average of 2.75 μ in width. Oral pouch well developed, extending beyond the middle of the body. Anterior and recurrent flagella as in *R. bradypi*. Nucleus spherical and near the anterior border of the cytostome.

Cysts lemon-shaped, hyaline, having a slight blunt projection at the narrower end measuring from 3.4-5.2 μ with an average of 4.19 μ in length and from 3.0-4.0 μ with an average of 3.5 μ in width. Cytoplasm finely granular. Cyst wall distinct. Nucleus central, showing well defined central karyosome, nuclear membrane altogether obliterated. The looped strands in position of cytostomal border persisting. Flagella reduced to pigmented fibrils showing as lines within.

This species was first recorded by Wenyon (1926) in guinea pigs, but was named by Hegner & Schumaker. Wenyon (1921) referred to a species of *Embadomonas* very similar to *Embadomonas intestinalis* he observed in a guinea pig in Major Urquhart's Laboratory in Macedonia.

HOST : The Guinea Pig, *Cavia porcellus* Linn.

### 8. *Retortamonas cuniculi* (Collier & Boeck)

(Figs. 25-26)

*Embadomonas cuniculi* Collier & Boeck, *J. Parasitol.*, 2 : 131-140.

Trophozoites generally ovate, sometimes with posterior end drawn out into a tail-like process, measuring from 7.5 to 13.0 μ in length and 5.5 to 9.5 μ in breadth. Anterior end rounded, bent towards oral pouch so as to form the heel of a slipper. Dorso-ventral diameter comparatively greater than the transverse diameter. Cytostome occupying anterior quarter of the body. Siderophilous borders fragile and rigid, not capable of movements. Cytostomal flagellum comparatively thick, leaving cytostome at its anterior end as a free lash. Anterior flagellum fragile, as long as or even longer than the body. Posterior flagellum hardly one-half or two-thirds of the body length. Nucleus faintly visible in the anterior part of the transparent cytoplasm, approximately spherical, possessing a well differentiated siderophilous nuclear membrane. Karyosome distinct, con-

nected to centrosome by an intranuclear rhizoplast. Extranuclear rhizoplast connecting blepharoplast to the centrosome. Blepharoplasts lie side by side on the nuclear wall. Posterior granule situated at the anterior end of cytostome together with the posterior flagellum.

Cysts hyaline, shaped like grape seed, surrounded by a slightly more refractive, uniformly thick cyst wall, measuring from 5.0 to 6.5 μ with an average of 6.0 μ in length and 3.5-4.0 μ with an average of 3.8 μ in width. Cytoplasm finely granular. Nucleus central in position. Nuclear membrane, central karyosome and intra-nuclear rhizoplasts easily traceable. Other structures representing the remains of cytostomal fibres and flagella reduced to black lines. Blepharoplasts visible at the anterior end of the cyst.

The oral lips in this species are not wavy as in *R. agilis* and *R. alexeiffi*. Cytostome immobile, resembling *R. intestinalis* but is not elongated, sac-like as in *R. sinensis*. Cytostomal flagellum thick, contractile and capable of undulating vibrations. In *R. intestinalis* the posterior flagellum is thick and straight.

HOST : Caecum of rabbit, *Oryctolagus cuniculus* (Linn.)

### 9. *Retortamonas dobelli* (Bishop)

*Embadomonas dobelli* Bishop, 1931, *Parasitology*, 23 : 286-300.

Trophozoites widest in the middle, tapering slightly anteriorly and more rapidly posteriorly, measuring from 7.0 to 11.0 μ with an average of 8.5 μ in length and 4.0 to 8.0 μ with an average of 6.0 μ in width. Anterior end rounded but lacks flexure and torsion observed in other species. Posterior end usually rounded and rarely pointed. Cytostome large, approximately occupying half the length of the body, deepest at its anterior end. Siderophilous borders well defined and slightly undulating. Supporting fibrils and lips usually extending round the anterior end of the depression, posterior side with fibril on one side while the other side appears to be devoid of it. Anterior flagellum as long as or a little longer than the body, very slender and delicate. Recurrent flagellum exceedingly delicate, thick basally and tapering gradually to the tip, projecting some distance beyond the limit of the oral pouch. Flagella arising from minute and separate blepharoplasts. Nucleus well developed, spherical, lying at the extreme anterior end of the body. Nuclear membrane distinct, karyosome usually present. Blepharoplasts two minute and spherical granules lying close to the inner side of the lip at the anterior end of the peripheral chromatin of the nucleus.

Cysts ovate, colourless with a slight point at one end, measuring on the average 6.0 x 4.5 μ. Freshly formed cysts tend to be round, but become pointed at one pole when mature. It is extremely difficult to make out any internal structures in new cysts but most of the structures are definitely distinct in older cysts. Nuclear peripheral chromatin and central karyosome quite distinct but in various stages of development. Basal granules and cytostomal fibrils invariably present. The course of the two flagella definitely followed in some individuals.

HOSTS : Various toads and frogs, *Acris gryllus*, *Bufo vulgaris*, *B. valliceps*, *Rana catesbiana*, *R. clamitans*, *R. pipiens*, *R. temporaria* and *Salamandra maculosa*.

### *10. Retortamonas gryllotalpae* Grassi

(Figs. 6-8)

*Retortamonas gryllotalpae* Grassi, 1879, *Gazz. Med. Ital. Lomb.* 39 : 445-448.
*Plagiomonas gryllotalpae* Grassi, 1881, *Atti Soc. Ital. Sci. Nat.* 24 : 135-224.
*Bodo gryllotalpae* Doflein, 1901, *Die Protozoen als Parasiten, Jena.*

Trophozoites pyriform, with a spindle-shaped central region, prolonged anteriorly into a dorsally tilted cone and pulled out posteriorly into a tapering caudal spike. Measuring from 7.0 to 19.0 μ with an average of 10.7 μ in length and from 2.2 to 6.0 μ with an average of 4.0 μ in width. Anterior end slightly pointed in living specimens and variously round in preserved material. Posterior end sharply pointed like a spike. Cytostome occupying large part of the ventrum, about one third of the body length. Siderophilous borders well developed, furnished with a long fibril on one side and a shorter one on the other. Free flagellum slender and shorter than the cytostomal flagellum. Posterior flagellum wavy, thicker in proximal part, confined to the oral pouch. Nucleus situated a little further away from the anterior end, spherical or oval in outline with poorly differentiated nuclear wall, and thin chromatin layer against the membrane. Karyosome made up of one or more faintly visible granules. Blepharoplasts close together, near the anterior border of the cytostome.

Cysts rather symmetrical, hyaline, surrounded by a distinct comparatively more refractive cyst wall, nearly twice as long as broad with round poles. Measuring 6.8 μ in length and 3.5 μ in width. Remains of cytostomal fibres and flagella distinctly visible in the cyst.

HOST : The European mole cricket, *Gryllotalpa gryllotalpa* Linn. and the Oriental mole cricket, *Gryllotalpa africana* Linn.

## *11. Retortamonas intestinalis* (Wenyon & O'Connor)

(Figs. 38-44)

*Waskia intestinalis* Wenyon & O'Connor, 1917, *Human intestinal Protozoa in the Near East*, London.

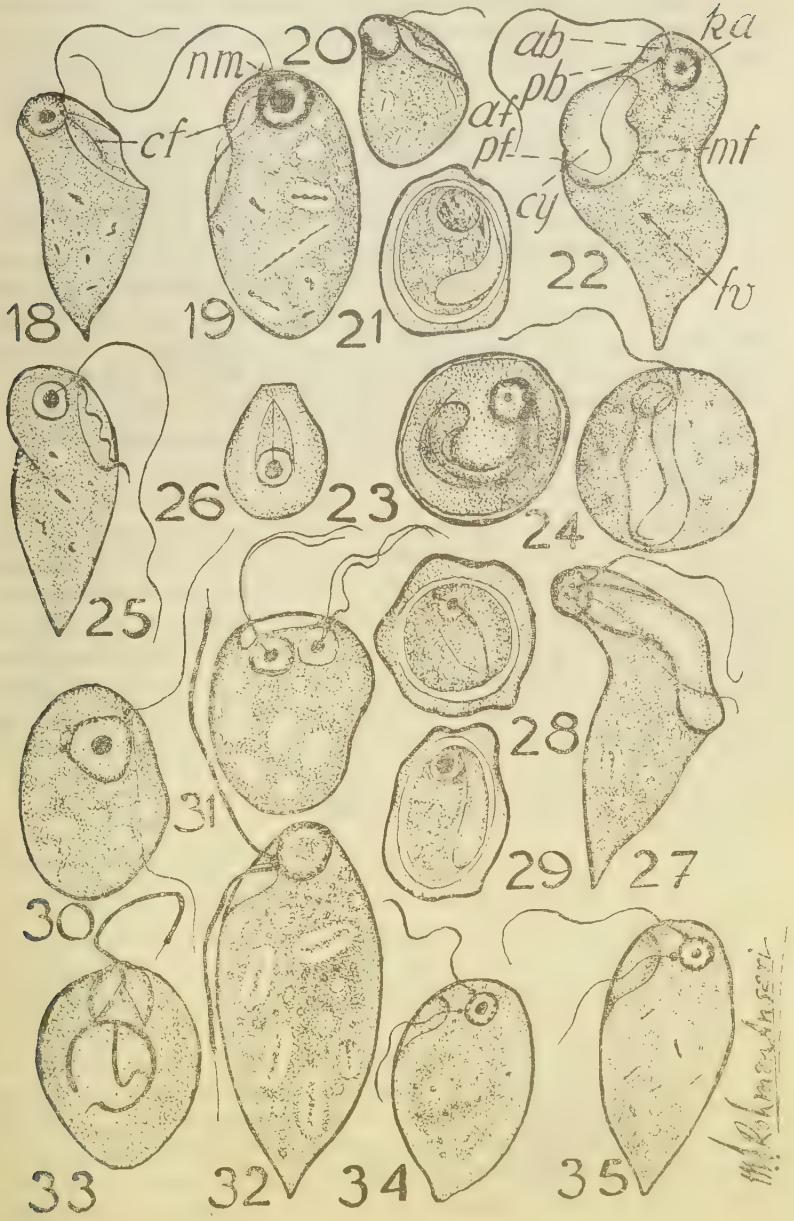
*Embadomonas intestinalis* Chalmers & Pekkola, 1918, *J. Trop. Med.* 21 : 129-133.
*Enteromonas bengalensis* Chatterjee, 1919, *Indian J. Med. Res.* 6 : 380-382.

Trophozoites very variable in shape, commonly pyriform and rarely almost spherical. Anterior end blunt, posterior end terminating in a point. Wenyon & O'Connor (1917) described its appearance as bird-like while Mackinnon (1931) called it slipper-shaped. Measurement from 3.5 to 9.0 μ with an average of 5.6 μ in length and from 1.5 μ to 6.0 μ with an average of of 3.0-3.5 μ in breadth. Individuals about 17 μ long frequently encountered. Cytostome antero-lateral, occupying almost one-half of the body length, lip of one side more weakly developed than that of the other. Anterior flagellum long and thin, ending bluntly. Posterior recurrent flagellum passing some distance through the oral pouch before leaving the body, thicker and stouter and tapering to a point. Nucleus spherical and vesicular, situated at the anterior end of the body just in front of the cytostome. Nuclear membrane delicate but distinct. Karyosome central. Blepharoplasts two, spherical, in contact with the nuclear membrane, each giving rise to the flagellum and also connected through extra-rhizoplast to the centrosome and karyosome.

Cysts minute, pear-shaped, hyaline, surrounded by a distinct wall. Measuring from 4.0 to 9.0 μ with an average of 6.1 microns in greatest length and 2.5-4.5 μ in width. The contents composed of finely granular cytoplasm, nucleus and deeply staining looped fibrils representing the margins of the cytostome.

Hogue (1936) dealt with four races of *R. intestinalis*. Cysts of one strain are with definite cyst wall and clearly defined inner and outer limits. These cysts were also more sticky. The length of the flagella

Figs. 18-21 : *Retortamonas alexeiffi* (Mackinnon)— (18) trophozoite with torsion of the anterior end and caudal spike, (19) globular trophozoite, (20) early stage, and (21) cyst. Figs. 22-24 : *Retortamonas blattae* (Bishop)— (22) vegetative form, (23) cyst and (24) individual in early stage of encystment. Figs. 25-26 : *Retortamonas cuniculi* (Collier & Boeck) — (25) vegetative form, and (26) cyst. Figs. 27-29 : *Retortamonas agilis* (Mackinnon)— (27) vegetative form, and (28-29) cysts. Figs. 30-31 : *Retortamonas termitis* (Kirby) — (30) vegetative form, and (31) trophozoite in binary division, with two nuclei. Figs. 32-33 : *Retortamonas mitrulae* Kirby & Honigberg — (32) vegetative form, and (33) frontal view of the trophozoite. Figs. 34-35 : *Retortamonas testudae* n. sp.— (34-35) vegetative form.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varies considerably in the trophozoites of the four races. In one with sticky cysts, the two flagella were of equal length while in others the posterior one was slightly longer than the anterior one.

HOST : The man.

### *12. Retortamonas mitrulae* Kirby & Honigberg

(Figs. 32-33)

*Retortamonas mitrulae* Kirby & Honigberg, 1950, *Univ. Calif. Publ. Zool.*, 55 : 35-66

Trophozoites small, and somewhat longer than broad, measuring from 3.5 to 10.0 μ with an average of 5.5 μ in length and 3.0 to 5.5 μ with an average of 4.0 μ in width. Anterior end broadly rounded. Posterior end blunt, in some specimens terminating in a small point. Cytostomal region broadly oval, beginning near the anterior end and terminating at about a quarter to one-third of the body length. A single cytostomal fibril surrounding the anterior edge with two approximately equal arms along the sides, anteriorly bordering a curved triangular or trapezoidal membrane that bounds the anterior surface of the oral depression. Flagella of almost equal length and thickness, very slightly shorter than the body length; both terminating in a fine filament. Recurrent flagellum emerging within the anterior part of cytostome, basal part passing longitudinally within and along cytostome. Nucleus spherical, situated in the extreme rounded anterior margin of the body. Chromatin substance interior to the nucleur membrane appears as a continuous narrow ring. Karyosome central and large. Blepharoplasts situated just above the inner edge of the anterior part of the cytostome and against the nuclear membrane.

HOST : The wallaroo, *Macropus robustus*.

### *13. Retortamonas ovis* (Hegner & Schumaker)

*Embadomonas ovis* Hegner & Schumaker, 1928, *J. Parasitol.*, 15 : 37.

Trophozoites ovate, broadly rounded anteriorly and gradually narrowing posteriorly. Posterior end blunt. Measuring from 4.5 to 6.1 μ with an average of 5.3 μ in length and from 2.7 to 4.7 μ with an average of 3.4 μ in width. Cytostomal region reniform, anterior margin narrow, extending posteriorly for more than half of the body length. Marginal fibrils of consistent structures, running in a smooth curve with the posteriorly directed arms. Flagella more or less equal in length. Anterior flagellum more slender than the recurrent flagellum which emerges from within the anterior part of the cytostome, and passes longitudinally within the oral pouch before projecting laterally in the middle region as free

flagellum. Nucleus situated anteriorly and close to the cytostome. Peripheral ring of chromatinic substance and central karyosome distinct. Blepharoplasts present, situated above the anterior part of the cytostome and on the nuclear membrane.

Cysts small, pear-shaped with regularly thick cyst wall, measuring from 4.0 to 6.0 μ with an average of 4.6 μ in greatest length and from 3.1 to 4.4 μ with an average of 3.8 μ in small diameter. Nucleus having a delicate nuclear membrane and distinct central karyosome. A deeply staining looped fibril surrounding the nucleus present. The remains of the flagella indistinct.

HOST : The sheep, *Ovis aries.*

### *14. Retortamonas phyllophagae* (Travis & Becker)

*Embadomonas phyllophagae* Travis & Becker, 1831, *Iowa State Coll. J. Sci.* 5 : 223-235.

Trophozoites robust, typically slipper-shaped, but the young forms more or less pyriform, measuring from 4.75 to 9.5 μ in length and 4.17 to 4.9 μ in greatest width. Anterior end round, slightly curved towards the dorsum and to one side so as to form the heel of the slipper. Posterior extremities rounded, terminating in a small triangular projection. Cytostome large, directed anterolaterally and occupying one-half of the body length. Cytostomal margin convoluted and strengthened with well-developed and flexible siderophilous fibrils. Flagella of unequal length, but of same thickness, anterior flagellum slightly shorter than the body, recurrent flagellum almost as long as the oral pouch. Nucleus spherical, situated anteriorly with chromatin arranged in a large karyosome consisting of several granules or a crescent-shaped mass against the periphery of the nucleus. Blepharoplasts situated in the anterior part of the body, posterior granule located near the cytostome, while the anterior one placed away on the nuclear membrane.

HOST : The white grubs, *Phyllophaga* spp. : Coleoptera.

### *15. Retortamonas ruminatum* (Knowles & Das Gupta)

(Figs. 36-37)

*Embadomonas ruminatum* Knowles & Das Gupta, 1931, *Indian J. Med. Res.*, 18 : 1301.

Trophozoites very variable in form, commonly pyriform with a pointed tail end, and measuring from 6.5 to 9.0 μ with an average of 7.9 μ in length and 2.0-4.0 μ with an average of 3.1 μ in width. Cytostome anterior and prominent. Nucleus spherical, situated at the extreme anterior pole of the body. Anterior flagellum comparatively more fragile than the intracytostomal flagellum. Blepharoplasts minute granules

on the nuclear membrane towards the cytostome, one near the anterior end of the cytostome giving rise to the intra-cytostomal flagellum while the other towards the anterior end issuing the free flagellum.

Cysts ovoid, sometimes pyriform, very small in size, measuring 3.0-4.5 μ in greatest length and slightly less in width. Internal structures faintly visible.

HOST : The Indian bull, *Bos indicus* Linn., India.

### *16. Retortamonas sinensis* (Faust & Wassell)

(Figs. 53-54)

*Embadomonas sinensis* Faust & Wassell, 1921, *China Med. J.*, 35 : 543.

Trophozoites elongately oval or eugleniform. Quiescent forms presenting variable shape, commonly elongate and attenuate, particularly in the posterior half and on stimulation assuming the normal obovate form. Motile forms on an average measure 13.4-14.0 μ in length and 4.2-5.2 μ in width, quiescent form 10.0 μ x 7.0 μ, attenuated individuals as long as 20 μ. Anterior end rounded, with a twist in the middle, and terminating in a blunt caudal point, appearing like a pea-pod. Cytostome originates a little away from the anterior end, obliquely submarginal in position, wide and pouch-like in quiescent individuals, but elongate gullet-like and slightly spirally twisted in the attenuates. Apart from definite directions, marked diffrentiation between the anterior and posterior flagella wanting. Nucleus comparatively smaller than in other species, lies conspicuously away from the anterior margin of the cytostome, towards the frontal pole of the organism. Blepharoplasts placed at an appreciable distance from the nucleus and the anterior end of the cytostome. Neuromotor connections not distinct.

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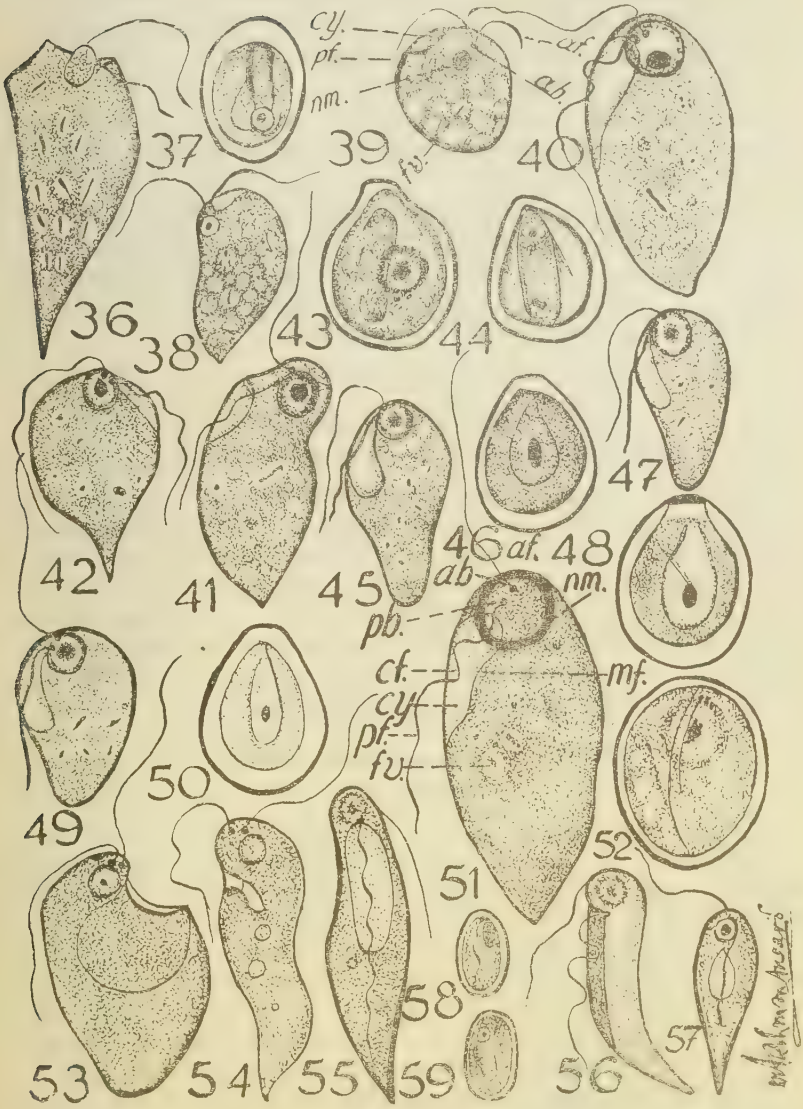
Figs. 36-37 : *Retortamonas ruminatum* (Knowles & Das Gupta)— (36) vegetative form, and (37) cyst. Figs. 38-44 : *Retortamonas intestinalis* Wenyon & O'Connor — (38) young trophozoite (profile), (39) young trophozoite (end on view), (40-41) typical individuals, one showing the torsion of the anterior end, (42) an individual in early phase of encystment, and (43-44) cysts. Figs. 45-46 : *Retortamonas caviae* (Hegner & Schumaker) — (45) vegetative form, and (46) cyst. Figs. 47-48 : *Retortamonas bradypi* (Hegner & Schumaker)— (47) vegetative form, and (48) cyst. Figs. 49-50 : *Retortamonas ovis* (Hegner & Schumaker)— (49) vegetative form, and (50) cyst. Figs. 51-52 : *Retortamonas dobelli* Bishop - (51) vegetative form and (52) cyst. Figs. 53-54 : *Retortamonas sinensis* Faust & Wassell— (53) spherical individual, and (54) elongate individual. Figs. 55-58 : *Retortamonas belostomae* (Brug) — (55) frontal view of the trophozoite, (56) side view of the trophozoites, (57) young trophozoite, and (58) cyst. Fig. 59 : *Retortamonas sp.* — Cyst.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Cysts ovate or pear-shaped. Cyst wall distinct and clearly separated from the animal enclosed in it. On an average the cysts measure 6.0 μ in length and 3.0 μ in width. It is extremely difficult to make out any internal structures. A small nucleus is the only structure visible in the finely granular and homogeneous cytoplasm.

Wenyon (1926) considers it exceedingly doubtful if *R. sinensis* is distinct from *R. intestinalis* especially when encysted forms are similar in both the species.

*Retortamonas sinensis* was discovered from diarrhoeic stools of Chinese patients in Wuchang (China) in July, 1921. In 1933, Watt found similar organisms in the diarrhoeic stools of patients in Peiping (China) and succeeded in growing them on Wenyon's medium and thus confirmed the validity of the species.

HOST : The man, China.

### *17. Retortamonas termitis* (Kirby)

*Embadomonas termitis* Kirby, 1932, *Parasitology*, 24 : 293.

Trophozoites elongate, measuring from 3.0 to 6.5 μ with an average of 5 μ in length and from 2.5 to 4.5 μ with an average of 3.5 μ in greatest breadth. It is rounded at both ends, cytostomal depression located in the anterior portion. Posterior flagellum trailing and somewhat longer than the body. Nucleus situated near the anterior end of the body. Karyosome central, of moderate size, with chromatinic granules on the nuclear membrane. Blepharoplasts antero-lateral and very close to the nuclear membrane.

HOST : Termite, *Amitermes beaumonti* Banks, Panama.

### *18. Retortamonas testudae* sp. nov.

(Figs. 34-35)

Trophozoites fusiform or ovate in general shape, measuring 12.0-19.0 μ in length. Anterior end rounded while the caudal end acutely angulate. Ovate organisms with very minute caudal angle. Cytostomal region broadly oval in form with its anterior margin a short distance away from the nucleus and extending posteriorly for about one-quarter to one-third of the body length. Anterior flagellum more or less as long as the body. Recurrent flagellum emerging from within the anterior part of the cytostome, traversing for some distance before projecting laterally in the middle as a free flagellum, comparatively smaller than the anterior flagellum. Nucleus circular and almost half as large as in the allied species, located a little away from the anterior margin of the cytostome. Central karyosome distinct. Blepharoplasts situated just above the inner

edge of the anterior part of cytostome but closer to the nucleus and appearing to be on the nuclear membrane.

Wenyon (1926) encountered *Retortamonas* in the intestinal contents of the tortoise, *Testuda argentina*. He found these flagellates resembling the forms he observed in frogs. The present author compared the figures presented by Wenyon with those of *Retortamonas dobelli* infesting frogs and toads. Apart from host differences, two forms infesting tortoises and amphibians respectively are differentiated from each other on the bases of size and shape of trophozoites, relative length of the flagella, characters of of cytostome, nucleus, and the position of blepharoplasts.

HOST : The tortoise, *Testudo argentina*, London.

### *19. Retortamonas wenrichi* Stabler.

(Figs. 9-14)

*Retortamonas wenrichi* Stabler, 1944, *J. Parasitol.*, 30 : 173.

Trophozoites relatively large with remarkably long tenuous tail. Anterior end frequently terminating in a short, conical projection. Body proper ranges from 12.2 to 19.0 μ with an average of 16.0 μ in length and 3.8 to 8.4 μ with an average of 6.2 μ in width. Posterior spike characteristic, measuring from 3.1 to 58.5 μ with an average of 23.2 μ. Length from the front to the caudal end varies from 16.7 to 76.0 μ with an average of 39.2 μ. The caudal extension very frequently looped and twisted and is a true spike. Precystic forms tail-less, and encountered occasionally. Cytostome distinct, hyaline anteriorly, bordered on one side by a longer chromophile-fibre (parabasal) and on the other by a short fibril (parastyle), both fibres frequently thicker near the point of origin. Parabasal fibre usually follows a wavy course, extends to the middle of the body and then runs across to continue some distance back to the anterior end, and may sometimes be accompanied by another stainable thread. Flagella approximately equal, generally longer than the body in length, trailing or recurrent flagella not showing marked association with the oral pouch. Nucleus situated close to the anterior end. Central karyosome and peripheral chromatin granules frequently very distinct. Blepharoplasts minute, spherical granules present at the origin of flagella and oral fibres.

Cysts roughly oval surrounded by a distinct cyst wall and usually tapering towards the anterior end, showing a thick, deeply staining cap as previously noted in *R. bradypi* and several other races of *R. intestinalis*. Nucleus located anteriorly. A tangle of fibres and threads extending

posteriorly. Size varying considerably from 6.1 to 8.4 μ with an average of 7.3 μ in length and from 4.6 to 6.1 μ with an average of 5.1 μ in greatest width.

HOST : The common mole cricket, *Gryllotalpa hexadactyla*, Pennsylvania

### *20. Retortamonas wenyoni* (Fonseca)

*Waskia wenyoni* Fonseca, 1917, *Mem. Inst. Oswaldo Cruz.*, 12 : 65 ; *(Brazli Medico*, 31 (49) : 416).

*Embadomonas wenyoni* Hegner & Taliaferro, 1924, *Human Protozoology.*

Trophozoites more or less heart-shaped or rounded. Measuring about 14.0 μ in length and 12.0 μ in width. Anterior pole broadly rounded, posterior pole angular. In some specimens caudal end blunt. Cytostome originally as a slight convexity from the anterior pole and extending to the posterior as far as one fourth of the body length, bordered with two lips which are edged with fibrils arising from the inferior blepharoplasts. Flagella approximately half as long as the body. Anterior flagellum slender, while the recurrent one thick and undulating. Blepharoplasts maintain their position as in other species. The nucleus is spherical and characteristic of the genus.

HOST : The South American monkey, *Cebus* (Alouta) *caraya* Humboldt. Kessel (1926) found *Retortamonas* (*Embadomonas*) in *Macacus* Monkeys in China. Wenyon (1926) and Hegner (1928) consider that this species closely resembles *R. intestinalis* of man and that it is a distinct species, seems very doubtful.

### *21. Retortamonas* sp.

(Fig. 39)

Wenyon (1921, 1926) cultivated some flagellates belonging to the genus *Retortamonas* from the intestinal contents of the rats without giving any specific name. The present author has encountered similar cysts in *Mus musculus* Linn.

HOST : *Mus musculus* Linn.

TABLE I

**Statement showing Measurements (in microns) of Trophozoites and Cysts of *Retortamonas***

| Species | Trophozoites | | | | | | Cysts | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length | | | Breadth | | | Length | | | Breadth | | |
| | mln. | max. | aver. | min. | max. | aver. | min. | max. | aver. | min. | max. | aver. |
| 1. *R. agilis* ... ... a | 4.0 | 11.0 | — | 1.5 | 3.0 | — | 3.5 | 4.0 | — | 3.0 | 4.0 | — |
| b | 8.0 | 14.0 | — | 4.5 | — | — | — | — | — | — | — | — |
| 3. *R. alexeiffi* ... ... a | 7.0 | 16.0 | 11.5 | 5.0 | 9.0 | 7.0 | 5.0 | 6.0 | — | 4.0 | 5.0 | — |
| b | 12.0 | 16.0 | — | 4.5 | 6.4 | — | — | — | — | — | — | — |
| 3. *R. belostomae* ... ... | — | — | — | — | — | — | — | — | 6.0 | 3.0 | 4.0 | 3.5 |
| 4. *R. blattae* ... ... | 6.0 | 9.0 | 7.0 | 5.0 | 7.0 | 6.0 | 5.0 | 6.0 | 5.5 | 4.0 | 5.0 | 4.5 |
| 5. *R. bradypi* ... ... | 4.0 | 6.5 | 4.8 | 1.5 | 3.2 | 2.25 | 4.3 | 5.5 | 4.9 | 3.6 | 4.4 | 4.1 |
| 6. *R. caudacus* ... ... a | 6.0 | 18.0 | 10.0 | 3.0 | 6.0 | 5.0 | — | — | — | — | — | — |
| b | — | — | 14.0 | — | — | 5.0 | 5.0 | — | — | 2.0 | 3.0 | — |
| 7. *R. caviae* ... ... | 4.0 | 7.0 | 5.5 | 2.0 | 4.0 | 2.7 | 3.4 | 5.2 | 4.2 | 3.0 | 4.0 | 2.7 |
| 8. *R. cuniculi* ... ... | 7.5 | 13.0 | 9.5 | 5.5 | 9.5 | 5.5 | 5.0 | 6.5 | — | 3.5 | 4.0 | — |
| 9. *R. dobelli* ... ... | 6.0 | 11.0 | — | 4.0 | 8.0 | — | — | — | — | — | — | — |
| 10. *R. gryllotalpae* ... ... | 7.1 | 16.0 | 10.7 | 1.4 | 3.5 | 2.1 | 6.0 | — | — | 3.9 | — | — |
| 11. *R. intestinalis* ... a | 4.0 | 9.0 | — | 3.0 | 4.0 | 4.0 | 4.0 | 9.0 | — | 2.5 | 4.8 | — |
| b | 15.0 | 16.0 | — | 2.2 | 3.3 | — | 4.5 | 7.0 | — | 3.0 | 4.5 | — |
| 12. *R. mitrulae* ... ... | 3.5 | 7.5 | 5.5 | 3.0 | 5.5 | 4.0 | — | — | — | — | — | — |
| 13. *R. ovis* ... ... | 4.0 | 6.0 | 5.27 | 2.7 | 4.7 | 3.4 | 4.6 | — | 5.0 | 3.1 | 4.4 | 3.8 |
| 14. *R. phyllophagae* ... | — | — | — | — | — | — | — | — | — | — | — | — |
| 15. *R. ruminatum* ... ... | 6.5 | 9.0 | — | 2.0 | 4.0 | — | — | 4.5 | — | — | 3.5 | — |
| 16. *R. sinensis* ... ... | 1.0 | 20.0 | 14.0 | 4.2 | 7.0 | — | — | — | 6.0 | — | — | 3.0 |
| 17. *R. termitis* ... ... | 3.0 | 6.5 | 5.0 | 2.5 | 4.5 | 3.5 | — | — | — | — | — | — |
| 18. *R. testudae* ... ... | 12.0 | 19.0 | — | — | — | — | — | — | — | — | — | — |
| 19. *R. wenrichi* ... ... | 12.2 | 19.0 | 16.0 | 3.8 | 8.4 | 5.9 | — | — | — | — | — | — |
| 20. *R. wenyoni* ... ... | — | — | 14.0 | — | — | 12.0 | — | — | — | — | — | — |

TABLE II

## Host-Parasite Index

MAMMALIA :

1. *Bos indicus* Linn. : Ungulata ; Bovidae
   *Retortamonas ruminatum* (Knowles & Das Gupta) ; India.
2. *Bradypus griseus griseus* : Edentata ; Bradypodidae
   *Retortamonas bradypi* (Hegner & Schumaker) : Panama.
3. *Cavia cabaya* Humb : Rodentia ; Caviidae
   *Retortamonas caviae* (Hegner & Schumaker); Panama.
4. *Cebus caraya* Humb. : Primates ; Cebidae
   *Retortamonas wenyoni* (Fonseca); South America.
5. *Homo sapiens* Linn. : Primates ; Hominidae
   *Retortamonas intestinalis* (Wenyon & O'Connor)
   *Retortamonas sinensis* Faust & Wassell ; China.
6. *Macacus lasiotes* Gray : Primates ; Cercopithecidae
   *Retortamonas wenyoni* (Fonseca)
7. *Macropus robustus* Gould : Marsupialia ; Macropodidae
   *Retortamonas mitrulae* Kirby & Honigberg
8. *Mus musculus* Linn. : Rodentia ; Muridae
   *Retortamonas* sp.
9. *Oryctolagus cuniculus* (Linn.) : Rodentia ; Leporidae
   *Retortamonas cuniculi* (Collier & Boeck)
10. *Ovis aries* Linn. : Ungulata ; Bovidae
    *Retortamonas ovis* (Hegner & Schumaker)
11. *Rattus* (*Epimys*) *norvegicus* Klien : Rodentia ; Muridae
    *Retortamonas* sp.
12. *Rattus rattus* Linn. ; Rodentia ; Muridae
    *Retortamonas* sp.

REPTILIA :

13. *Testudo argentina* : Chelonia ; Testudinidae
    *Retortamonas testudae* n. sp.

AMPHIBIA :

14. *Acris gryllus*
15. *Bufo vulgaris* : Bufonidae
16. *Bufo vulliceps* : Bufonidae
17. *Rana catesbiani* : Ranidae
18. *Rana clamitans* : Ranidae
19. *Rana pipiens* : Ranidae
20. *Rana temporaria* : Ranidae
21. *Salamandra maculosa*

→ *Retortamonas dobelli* Bishop

INSECTA :

22. *Amitermes beumonti* Banks : Isoptera
    *Retortamonas termitis* (Kirby)
23. *Belostoma* sp. : Hemiptera
    *Retortamonas belostomae* (Brug)
24. *Blatta orientalis* Linn. : Orthoptera
    *Retortamonas blattae* (Bishop)
25. *Gryllotalpa africana* Linn. : Orthoptera
    *Retortamonas gryllotalpae* Grassi
26. *Gryllotalpa gryllotalpa* Linn. : Orthoptera
    *Retortamonas gryllotalpae* Grassi
27. *Gryllotalpa hexadactyla* : Orthoptera
    *Retortamonas wenrichi* Stabler
28. Gyrinidae : Coleoptera
    *Retortamonas caudacus* Geiman
29. *Phyllophaga* sp. : Coleoptera
    *Retortamonas phyllophagae* (Travis & Becker)
30. Trichoptera (Caddis flies)
    *Retortamonas agilis* (Mackinnon)
31. *Tipula* sp. : Diptera
    *Retortamonas agilis* (Mackinnon)
    *Retortamonas alexeiffi* (Mackinnon)

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# A Contribution to the Charales of West Pakistan

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Charales is a small group of freshwater Algae. Wood (1952) has recently listed 7 genera with 292 species from all over the world. According to Groves (1923) 35 species, belonging to the genera *Nitella* Agardh, *Tolypella* (Braun) Leonh. *Chara* Linn., *Nitellopsis* Hy and *Lachnothamnus* Leonh. are found in the Indo-Pakistan Sub-Continent, and out of these the following species occur in West Pakistan : 1. *Nitella hyaline* (DC.) Agardh ; 2. *Tolypella glomerata* (Desv.) Leonh. ; 3. *T. hispanica* Nordstedt ex Allen ; 4. *Chara canescens* (Desv.) ; 5. *C. infirma* Braun.

This number is too small for a vast area like that of West Pakistan. It was, therefore, considered desirable to make a fairly intensive survey of the Charales from this region. The survey made yielded fruitful results and the total number of species of the Charales increased from 5 to 14.

## Family CHARACAE

Submerged aquatic green algae with a slender, branched stem, bearing branchlets at the nodes in whorls ; the antheridium producing free swimming sperms; oogonium surrounded by 5 spiral cells forming a coronula of 5 or 10 cells at the tip ; mature oospore surrounded by a variously ornamented membrane.

### KEY TO THE GENERA

Coronula composed of ten cells in two tiers *(Nitellae)*

Antheridia apical in the furcations of the branchlets above the oogonia. Ripe oospore laterally compressed.....1. *Nitella*

Antheridia lateral at the furcations of the branchlets. Ripe oospore terete.....2. *Tolypella*

Coronula composed of five cells in one tier *(Chareae)*

A single genus.....3. *Chara*

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## I. Nitella Agardh

Stem and branchlets always ecorticate ; normally two branches arising from a stem node; branchlets usually furcate ; antheridia terminal, produced between the forks of the branchlets; oogonia lateral ; coronula composed of ten cells in two tiers of five ; oospore laterally compressed.

### KEY TO THE SPECIES

Branchlets in each whorl in one series,
nearly uniform in length and extent of furcation.....1. *N. mucronata*

Branchlets in each whorl in three series,
those of the middle series much longer and more
compound than the inner and the outer.....2. *N. hyalina*

1. **Nitella mucronata** (Braun) Miquel in Van Hall, Fl. Belg. Sept. 2 : 428, 1840.

Monoecious. Stem moderately stout; internodes about twice the length of the branchlets. Whorls of 5 to 6 branchlets ; sterile and fertile whorls more or less similar. Branchlets of sterile whorls 1 to 3 times and those of the fertile 2 to 3 times furcate ; primary ray about half the length of the whole branchlet. At the first furcation 3 to 4 rays, and at the second 2 to 3 rays, of which 1 to 3 again furcate with 2 to 3 quarternary rays ; ultimate rays usually 2-celled, rarely 3-celled ; lower cell of the ultimate ray rounded at the apex ; the upper cell shorter, narrow, conical, acute, forming a mucro. Gametangia may be present at each forking. Oogonia solitary or geminate, globose, 188 to 209 μ long, 180 to 200 μ broad ; spiral cells showing 7 to 9 convolutions ; coronula 14μ high, 28μ broad, persistent. Oospore globose, dark brown, 111 to 167μ long, 111 to 153μ broad, with 6 to 7 prominent ridges; outer membrane thin, flexible, translucent, brown, reticulate. Antheridium about 188μ in diameter.

HABITAT : In freshwater ponds.

LOCALITY : Lahore, 9. 9. 1952 ; Lakhoder (Lahore), 4. 8. 1952.

As evidenced by the description of various authors the species is variable in the number of branchlets, number of furcation, the length of dactyles, the size of gametangia and ornamentation of the outer membrane of the oospore. The description of the writer's material closely agrees with that of Groves & Bullock-Webster (1920) differing only in the smaller gametangia.

2. **Nitella hyalina** (DC.) Agardh in Syst. Alg., p. 186, 1842.

Monoecious. Stem slender; internodes 2 to 4 times the length of the branchlets. Whorls of usually 24 branchlets in three series, 8 primary and 16 accessory, in two series, one above, the other below the primary branchlets. Primary branchlets thicker and longer, 2 to 3 times furcate ; primary rays about 1/2 to 3/4 the total length of the branchlets ; secondary rays 7 to 10, of which 2 to 3 simple, tertiary rays 4 to 7, with quarternary rays. Ultimate rays 2-celled, the lower cell tapering gradually to the apical cell ; the apical cell small, conical, pointed. Accessory branchlets once furcate into 4 or 5 rays. Oogonia and antheridia enveloped in mucus, borne on the primary branchlets at the second, third and the fourth forkings. Oogonia solitary, 500 to 600 μ long, 375 to 400 μ broad ; spiral cells showing 9 to 10 convolutions ; coronula about 28 μ high, 40 μ broad, persistent. Oospore flattened, black, 300 to 350 μ long, 250 to 300 μ broad, showing 7 to 8 inconspicuous ridges ; outer membrane thin; flexible, translucent, yellow, somewhat reticulate. Antheridium about 260 μ in diameter.

HABITAT : In ponds and ditches.

LOCALITY : Lakhoder (Lahore), 14. 10. 1952 ; Nowshera, 8. 2. 1953 ; Missan Kalar (Sheikhupura), 9. 9. 1949 ; Lakhoder (Lahore), 20. 2. 1953 ; Baluchistan, (leg. A. Braun).

This is the commonest species of *Nitella* in West Pakistan, found everywhere especially after rains. This can be distinguished from other species by the presence of mucus which envelops the younger parts of the plant. Fertile whorls form more or less dense heads. It thrives best in water-logged areas where large quantities of alkaline salts are present in the water. Plants from Missan Kalar are up to one foot long, while those from Lakhoder and Nowshera are about half this in size.

2. **Tolypella** (A. Braun) Leonh.

Branchlets usually furcate ; stem and branchlets entirely ecorticate ; antheridia lateral at the nodes of the branchlets ; coronula of 10 cells in 2 tiers of five ; oospore terete.

KEY TO THE SPECIES

Ultimate cells of the branchlets conical.....1. *T. prolifera*
Ultimate cells of the branchlets allantoid
Monoecious.....2. *T. glomerata*
Dioecious..... *(T. hispanica)*

1. **Tolypella prolifera** (Ziz ex Braun) Leonh. in Lotos, 13 : 57, 1863.

Monoecious. Stem stout, much branched. Sterile whorls of 8 to 12 branchlets, simple, 3 to 5 celled, of unequal size, the cells of each branchlet decreasing gradually in length and thickness towards the apex ; the apical cell bluntly conical. Fertile whorls in large dense heads ; one to twice furcate, with usually three lateral rays and one central ray ; the central ray either elongated or again divided with a central elongated ray ; ultimate rays 3 to 5-celled, acute, lower cell longer than the upper, ultimate cell conical, acute. Oogonia and antheridia occuring side by side at the bases of the whorls as well as at the branchlet nodes. Oogonia ellipsoidal, 450 to 550 μ long, 260 to 440 μ thick ; spiral cells showing 11 to 12 convolutions ; coronula about 45 μ high and 56 μ broad, persistent. Oospore ellipsoidal, brown, 325 to 340 μ long, 390 to 410 μ broad, showing 9 thin and prominent ridges ; outer membrane thin, flexible, translucent, smooth. Antheridia about 275 μ in diameter, sessile.

HABITAT : In slow running water.

LOCALITY : Chhota Ravi, Lahore, 10. 11. 1951 (leg. Dr Sultan Ahmad).

The plants are robust, about one foot long, much encrusted and of very dull appearance.

2. **Tolypella glomerata** (Desv.) Leonh. in Lotos, 13 : 57, 1863.

Monoecious. Stem moderately stout ; branches 2 to 6 at a node. Sterile whorls of 6 to 12 elongated branchlets ; branchlets 3 to 5-celled, the ultimate cell elongated, cylindrical and obtuse. Fertile whorls in dense compound heads of once forked branchlets. Rays 4 to 5, unequal, tapering ; the central ray longer than the lateral rays, 3 to 4-celled ; the lateral rays 3-celled ; ultimate cell allantoid, obtuse. Oogonia and antheridia produced at the nodes of the branchlets. Oogonia geminate, 2 to 5 at each node, stalked, ellipsoidal, 400 to 500 μ long, 300 to 350 μ broad ; spiral cells showing 9 to 10 convolutions ; coronula 35 to 50 μ high, 60 to 90 μ broad, with 7 to 10 thin ridges ; outer membrane thick, semi-rigid, semi-opaque, yellow, linearly granulated. Antheridia about 350 μ in diameter.

HABITAT.-In pools.

LOCALITY.-Quetta, 7. 6. 1953 (leg. I. I. Chaudhri) ; Quetta, (leg. J. H. Lace).

### 3. Chara Linn.

Stem and branchlets mostly corticate, rarely ecorticate ; stipulodes well developed or rudimentary ; oogonia and antheridia produced usually at the nodes of the branchlets ; oogonium above the antheridium; coronula composed of 5 cells in one tier ; oospore terete.

KEY TO THE SPECIES

Stipulodes in a single series.....(Haplostephanae)
Gametangia produced both at the base of the whorls as well as at branchlet nodes
Monoecious.....1. *C. corallina*
Dioecious.....2. *C. wallichii*
Gametangia produced only at the branchlet nodes.....3. *C. braunii*
Stipulodes in a double series.....(Diplostephanae)
Rows of cortical cells of the stem as many as the number of branchlets.....(Haplostichae)
A single species.....4. *C. canescens*
Rows of cortical cells of the stem twice as many as the branchlets.....(Diplostichae)
Primary cortical cells more prominent than the secondary.....5. *C. contraria*
Secondary cortical cells more prominent than the primary.....6. *C. vulgaris*
Rows of cortical cells of the stem three times as many as the branchlets.....(Triplostichae)
Dioecious..... *C. infirma*
Monoecious
Cortical cells of the branchlets twice as many as the bract cells
Primary cortical cells more prominent than the secondary.....7. *C. deliculata*
Primary cortical cells as prominent as the secondary.....8. *C. fragilis*
Cortical cells of the branchlets three times as many as the bract cells.....9. *C. brachypus*

1. **Chara corallina** Klein ex Willd. in Mem. Acad. Royal Berlin (1803) 86, 1805.

Monoecious. Stem stout, about 700 μ thick ; internodes very long, several inches in older parts, ecorticate. Stipulodes in one series, rudimentary, but in young parts of the plant elongated, acute. Whorls of 7 to 8 branchlets, each branchlet of 4 to 5 segments ; the upper segment small, conical, acute, sometimes bulbous at the base. Bract cells 3 to 4, long, acute, never developed at the ultimate node. Gametangia at the base of the whorls as well as on the branchlets. Oogonia with a long stalk, ovate-oblong, 700 to 800 μ long, 400 to 500 μ broad ; spiral cells with 9 to 10 convolutions ; coronula deciduous, 85 to 120 μ high, 165 to 200 μ broad. Oospore ovate-oblong, black, 480 to 690 μ long, 270 to 320 μ broad, with 7 to 8 prominent ridges ; outer membrane flexible, light yellow, granulate. Antheridium about 525 μ in diameter.

HABITAT : In freshwater ponds.

LOCALITY : Karachi, 1. 3. 1952 ; Jacobabad, 4. 9. 1952.

The species is characterized by its robust habit and annular incrustations. The branchlets are more or less incurved. It differs from *C. wallichii* in being monoecious and from *C. braunii* in the position of the gametangia, which occur both at the base of the whorls as well as on branchlet nodes.

2. **Chara wallichii** Braun in Abh. Koenig. Akad. Wiss. Berlin p. 107, 1882.

Dioecious. Male and female plants similar. Stem very stout, about 1.2 mm. in diameter, ecorticate. Stipulodes in one series, rudimentary. Whorls of 3 to 4 branchlets ; branchlets straight, as long as or longer than the internodes, of 4 to 6 segments ; apical cell long, slightly longer than the bract cell. Bract cells 2 to 4, moderately long, thick, acute; bracteoles similar, as long as the oogonia. Gametangia at the base of the whorls as well as at the branchlet nodes. Oogonia geminate both inside and outside the branchlet at the base of the whorl, 1 to 2 at the branchlet node, broadly ellipsoidal, 650 to 700 μ long, 450 to 520 μ broad ; spiral cells showing 7 to 8 convolutions ; coronula straight, 80 to 90 μ high, 150 to 200 μ broad, persistent. Oospore broadly ellipsoid, truncate at the base, black, 500 to 550 μ long, 350 to 400 μ broad, showing 6 to 7 prominent ridges ; outer membrane thick, black, opaque. Antheridia clustered at the base of the whorls, 1 to 2 at the lower internodes of the branchlets, about 500 μ in diameter.

HABITAT : In freshwater ponds.

LOCALITY : Lakhoder (Lahore), 1. 9. 1952, (female plants) ; Lahore, 2. 2. 1953, (male and female plants) ; Rawalpindi, (leg. R. R. Stewart, No. 808, female plants).

The plant may be easily recognized in the field by its spiky appearance and brittle nature.

The species was based on male plants collected by Braun from India in 1809. In 1922 Allen found both male and female plants and published a complete description of the species. It is fairly common in India, Burma and Pakistan. The writer's description agrees with the type material but differs in important details from the one given by Pal (1931). In the Burmese material gametangia are not found on the second internodes of the branchlets and are larger in size and the stem is also comparatively thin.

3. **Chara braunii** Gmelin in Fl. Bad. Alsat. 4 : 649, 1826.

Monoecious. Stem thick, encrusted in rings ; internodes as long as the branchlets, ecorticate. Whorls of 8 to 10 branchlets. Stipulodes in one series, alternating with the branchlets, spreading, usually long, variable in size, acuminate. Branchlets more or less straight, of 4 to 5 segments, uppermost shorter with a characteristic crown of 3 cells at the tip. Bract cells 5, variable in length, the anterior pair usually longer. Bracteoles like the anterior pair of the bract cells, slightly shorter in length than the oogonium. Gametangia produced at the lower 2 to 3 nodes of the branchlets but never at the base of the whorls. Oogonia 1 to 3, ellipsoidal to cylindrical, 650 to 700 μ long, 450 to 500 μ broad ; spiral cells showing 9 to 10 convolutions; coronula 160 to 200μ high, 300 to 350μ broad, spreading, apex rounded. Oospore ellipsoidal-cylindrical, black, 480 to 520 μ long, 275 to 300 μ thick with 8 to 9 ridges ; outer membrane thick, rigid, semi-opaque, black, faintly granulated. Antheridium about 250 μ in diameter.

HABITAT : In freshwater ponds and ditches.

LOCALITY : Missan Kalar (Sheikhupura), 21. 10. 1949 ; Kalashah Kaku (Sheikhupura) 7. 11. 1952 ; Chanawan (Gujrat), 17. 4. 1953 ; Sakesar 10. 4. 1955. (leg. S. Ahmad)

This is a variable species and several forms have been recognized. It closely resembles *C. nuda* Pal and *C. pashanii* Dixit but differs in the presence of a cluster of 2 to 3 short cells at the tip of the branchlets and better developed stipulodes. The absence of gametangia at the base of the whorls distinguishes it from *C. corallina* Klein ex Willd. and *C. succinata* Braun.

4. **Chara canescens** Desv. in Fl. de France. p 133, 1810.

Dioecious. Stem moderately stout ; internodes 2 to 4 times the length of the branchlets. Cortex haplostichous, about 8 peripheral cells surrounding a stem internode ; spine cells persistent, in clusters of three, slightly spreading, as long as or longer than the diameter of the stem, slender, acuminate. Whorls of 8 to 9 branchlets. Stipulodes in two series, well developed, long, slender, acuminate. Branchlets short, slightly incurved, of 6 to 8 segments ; the uppermost segment ecorticate, slightly longer than the subtending bracts. Bract cells 5 to 6, well developed, longer than the oogonium, slender, acuminate. Bracteoles variable, shorter or longer than the oogonium. Bractlet (a unicellular appendage which takes the place of antheridium in a female plant) small. Oogonium ellipsoid, 600 to 700 μ long, 400 to 500 μ broad ; spiral cells showing 13 to 15 convolutions ; coronula short, about 60 μ high, about 120 μ broad, straight. Oospore ellipsoid to ovoid, black. 450 to 600 μ long, 275 to 350 μ broad, with 10 to 13 inconspicuous ridges terminating in short basal claws ; outer membrane thick, brittle, opaque, reddish, faintly granulate. Antheridium about 300 μ in diameter.

HABITAT : In freshwater ponds.

LOCALITY : Rawalpindi, 1. 1. 1918. (leg. R. R. Stewart); Burj Shahi (Peshawar), 23. 12. 1952, (female plants) ; Peshawar (leg. Braun) ; Baluchistan (leg. Braun) ; Quetta (leg. J. H. Lace), Ucchali, 10. 4. 1952, (leg. S. Ahmad).

The species is already known from Quetta, Baluchistan, and Peshawar. Dr Stewart collected both male and female plants from Ratan Talab, Rawalpindi. His plants differ from those collected from Peshawar in the robust habit, acute tips of the branchlets and long, thick and blunt stipulodes. Male plants were collected from Rawalpindi and the antheridium is of about 300 μ in diameter. The male and female plants are both similar in this collection.

Groves & Bullock-Webster (1924) regard it as a unique species of *Chara* in reproducing parthenogenetically. They also regard it as a compact species with very slight variation. The plants from Rawalpindi and Peshawar markedly differ from each other and at least two distinct forms based on this material can be recognized.

With the exception of Egypt, this species is generally confined to the colder regions of the world.

The very long clustered spine cells make it distinct from all other haplostichous dioecious species.

5. **Chara contraria** Braun ex Kuetz. in Phyc. Germ. p. 258, 1845.

Monoecious. Stem stout, encrusted with lime ; internodes 2 to 4 times as long as the branchlets. Cortex diplostichous, 14 to 20 peripheral cells surrounding a stem internode ; primary cortical cells more prominent than the secondary ; spine cells solitary, on ridges, short, rounded to conical, deciduous. Whorls of 7 to 9 branchlets. Stipulodes in two series, very variable, rudimentary or one or both series well developed, thick or thin. Branchlets 2 to 3, incurved or speading, of 5 to 7 segments, upper 2 to 3 segments ecorticate. Bract cells 4 to 5, varying in length. Bracteoles long, exceeding the oogonium. Oogonium solitary, on corticate segments of the branchlets only, ellipsoid to cylindrical, 650 to 700 μ long, 450 to 500 μ broad ; spiral cells forming 13 to 15 convolutions ; coronula 150 to 200 μ high, 200 to 350 μ broad, spreading. Oospore ellipsoid to cylindrical, brown, 475 to 525 μ long, 275 to 300 μ broad ; showing 11 to 14 fine ridges ; outer membrane thin, semi-rigid, translucent, brown, granulate. Antheridium about 272 μ in diameter.

HABITAT : In pools, ponds, and ditches, also in slow running water.

LOCALITY : Ladhar (Sheikhupura), 13. 4. 1950 ; Chablat bridge (near Campbellpur), 2. 2. 1953 ; Peshawar, 6. 2. 1953 ; Burjshahi (Peshawar), 21. 4. 1952, (leg. Shams-ul-Islam Khan) ; Wah. 8. 2. 1953 ; Tibi Bungalow (near Chakwal), 7. 3. 1953 ; Dhok Subedar (Jhelum), 25. 3. 1953; Quetta, 7. 6. 1953, (leg. I. I. Chaudhri).

This is one of the commonest species of *Chara* in West Pakistan, with a wide range of localities and habitats, and found almost everywhere. It can tolerate large quantities of alkaline salts but thrives best in fresh water. It is commonly encrusted with lime.

It is very closely allied to *C. vulgaris* Linn. from which it is distinguished by the primary cortical cells more prominent than the secondary, smaller antheridia, brown oospore with granulate outer membrane and the occurrence of spine cells on the ridges.

6. **Chara vulgaris** Linn. in Sp. Pl. p. 1156, 1753.

Monoecious. Stem stout. Cortex diplostichous, 16 to 20 peripheral cells surrounding a stem internode, regular, secondary cortical cells more prominent than primary. Spine cells solitary, in furrows, short or long, whorls of 7 to 9 branchlets. Stipulodes in two series, well developed, obtuse. Branchlets spreading, of 6 to 8 segments, upper 1 to 3 ecorticate. Bract cells 5, variable in length, the posterior pair usually rudimentary, anterior pair longer than the oogonium. Bracteoles similar to the anterior pair of bract cells. Oogonia and antheridia only on the corticate segments

of the branchlets. Oogonia ellipsoid to cylindrical, broader towards the base, 600 to 700 μ long, 400 to 500 μ broad ; spiral cells forming 14 to 16 convolutions ; coronula 80 to 100 μ high, 150 to 250 μ broad, slightly spreading. Oospore ellipsoid, black, 430 to 520 μ long, 300 to 350 μ broad, showing 12 to 15 thin ridges ; outer membrane thin, flexible, translucent, yellow, tuberculate. Antheridium about 450 μ in diameter.

HABITAT : In running water, streams, drains, ditches, ponds.

LOCALITY : Abbottabad, 5. 11. 1952 ; Ladhar (Sheikhupura) 28. 12. 1952 ; Wah, 8. 2. 1953 ; Dhok Subedar (Jhelum), 25. 3. 1950 ; Tibi Bungalow (near Chakwal), 24. 3. 1953 ; Ziarat (Baluchistan), 7. 6. 1953, (leg. I. I. Chaudhri) ; Campbellpur (leg. Mrs Tristram).

This species was first collected in West Pakistan from Campbellpur by Mrs Tristram (Groves, 1923). It is as common as *C. contraria*. The plants are encrusted and can tolerate a fairly high concentration of salts. It is one of those few species which are found in fast running water. It is, however, less variable than *C. contraria*.

7. **Chara deliculata** Agardh in Syst. Alg. p. 130, 1824.

Monoecious. Stem slender ; internodes longer than the branchlets ; cortex regular, triplostichous, about 30 peripheral cells surrounding a stem internode ; primary cortical cells more broad than the secondary. Spine cells small, papilliform. Whorls of 7 to 10 branchlets. Stipulodes in two series, both well developed, upper twice as long as lower. Branchlets of 8 to 10 segments, straight, upper 1 to 2 segments ecorticate ; 12 to 14 peripheral cells surrounding the lowest corticate segment. Bract cells 7, anterior pair usually elongated but shorter than the oogonium. Bracteoles as long as the anterior pair of bract cells. Gametangia only at the nodes of cortical segments of the branchlets. Oogonium ovoid, 600 to 700 μ long, 450 to 550 μ broad ; spiral cells showing 14 to 16 convolutions ; coronula 120 to 170 μ high, 150 to 275 μ broad, straight or spreading. Oospore elliptical to oval, black, 450 to 500 μ long, 200 to 340 μ broad, showing 12 to 14 prominent ridges ; outer membrane thick, laminated, semi-rigid, semi-opaque, dark brown, finely granulate. Antheridium about 450 μ in diameter.

HABITAT : In ponds.

LOCALITY : Lahore, 3. 3. 1952 ; Nurpur (Sheikhupura), 6. 12. 1952 ; Lakhoder (Lahore), 2. 2. 1953.

This species is distinguished from the closely allied *C. fragilis* Desvaux, in having primary cortical cells more prominent than the secondary, more prominent stipulodes and the papilliform spine cells.

8. **Chara fragilis** Desv. in Fl. de France, p. 137, 1810.

Monoecious. Stem slender, the internodes as long as the branchlets. Cortex regular, primary cortical cells as broad as secondary ; spine-cells very small, rounded. Whorls of 7 to 8 branchlets. Stipulodes of both series rudimentary. Branchlets straight, of 8 to 9 segments, upper 1 to 3 ecorticate. Bract cells 7, anterior pair elongated, but shorter than the oogonium ; bracteoles longer than the oogonium. Gametangia solitary, produced on lower 1 to 4 branchlet nodes. Oogonium ellipsoid, 750 to 850 μ long, 500 to 650 μ broad ; showing 14 to 17 convolutions ; coronula 170 to 250 μ high, 200 to 350 μ broad, convergent. Oospore ellipsoid, tapering slightly below, black, 500 to 650 μ long, 325 to 450 μ broad, showing 12 to 15 prominent ridges ; outer membrane thick, laminate, semi-rigid, semi-opaque, dark brown, finely granulated. Antheridium about 500 to 550 μ in diameter.

HABITAT : In ponds.

LOCALITY : Missan Kalar (Sheikhupura), 19. 10. 1952 ; Lakhoder (Lahore), 2. 2. 1953 ; Hyderabad (Sind), 10. 6. 1953, (leg. I. I. Chaudhri).

It is a variable plant and the various collections differ in slight details, such as the size of the stipulodes.

9. **Chara brachypus** Braun in Hooker's Jour. Bot. 1 : 298, 1859.

Monoecious. Stem stout, thick ; internodes long, about 30 peripheral cells surrounding the stem internode. Cortex triplostichous, cells of the primary and secondary series equally developed, sometimes primary more broad. Whorls of 9 to 11 branchlets. Stipulodes in two series, well developed, upper longer than the lower. Spine cells small, acute. Branchlets incurved, lower branchlet segment very small, entirely corticate or upper 1 to 3 segments ecorticate ; 20 peripheral cells surrounding a lower branchlet internode. Bract cells 5 to 7, variable, anterior pair elongated, about half as long as the oogonium. Bracteoles exceeding the bract cells. Gametangia on the lower 1 to 3 segments of the branchlet. Oogonium more or less cylindrical, 659 to 775 μ long, 450 to 500 μ broad ; spiral cells forming 12 to 14 convolutions ; coronula 110 to 160 μ long, 230 to 325 μ broad, cells conical. Oospore oval, black, 450 to 520 μ long, 275 to 350 μ broad, showing 10 to 11 ridges ; outer membrane thin, rigid, translucent, densely granulate.

HABITAT : In ponds and slow running water.

LOCALITY : Shahdara, 25. 10. 1952 ; Haro bridge near Hasan Abdal, 4. 2. 1953.

In the Haro bridge plant, obtained from running water, the primary cortical cells are broader than the secondary and upper 2 or 3 segments of the branchlet are ecorticate. In specimens from Lahore the primary and secondary corticate cells are equally broad and the segments of the branchlets are corticate.

The species resembles *C. fragilis* but can be distinguished by the very short lowest branchlet segment, and by the rows of cortical cells of the branchlets which are three times as numerous as the bract cells.

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# On the Morphology of Scales in some Teleost Fishes

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A comparative study of the morphology of the scales, which could reveal the importance of scale characters in classification, and possibly throw a light on the phylogeny and the inter-relationships of the various groups of teleost fishes, has attracted relatively few workers. Even these few workers are not agreed among themselves in their interpretation of the various scale characters such as the circuli, radii and ctenia. The present paper embodies the results of a detailed morphological study of the scales of nineteen species of teleost fishes, belonging to six different families, and including both freshwater and marine forms.

I am indebted to Dr Hamid Khan Bhatti, Ph. D. (Cantab), F. N. I., for his help and encouragement throughout the course of this study.

## MATERIAL AND TECHNIQUE

Most of the specimens for the study of the scales were purchased from the local market, while a few were obtained from the Collection at the Natural History Museum, Government College, Lahore.

Since the morphology of the scales on the different regions of the body of even the same individual is not the same, it was necessary for a comparative study to take the scales from a precise, and as far as possible, identical location on the various fishes. The following particular scales have been studied :—

(i) One scale from the transverse series, lying just below the latinucleate one ;

(ii) One scale lying obliquely below that latinucleate scale which, when counted antero-posteriorly, is the *n*/15th, where *n* denotes the total number of the latinucleate scales ;

(iii) One scale lying at the antero-dorsal end of the base of the pelvic fin ;

(iv) One scale from the lateral line : the *n*/15th when counted from backwards ;

(v) One scale from the second longitudinal row below the dorsal fin, just above the middle scale of the lateral line.

When available, a few scales were collected from the head region also. A specimen in which any of the above five particular pairs of scales was missing, was rejected.

In general the scales from the first of the above-mentioned positions were found to be typical in all respects, while the others were somewhat abnormal in shape, size and other characters. The minute structures on the scales were usually studied in the unstained material, but for gross morphological studies the scales were stained. Eosin though quick and bright, did not stain differentially but gave good results when the same quantity of Orange-G was added to it. However, the best results were obtained with Picro-indigo-carmine.

It was found very difficult to make permanent whole mounts of the scales, because the scales mounted in Canada Balsam curled up on drying. Cockerell's (1943-47) method of using clamps and gummed labels was tried but without very satisfactory results. Fairly good results were obtained by mounting the scales in Canada Balsam, holding the coverslip down by a loop of thread round its ends, and drying it in an electric oven at about 60°C.

The scales were mounted with their rough, outer side facing upwards. Since the details of sculpture are not very distinct in a scale mounted in Canada Balsam, the scales were also examined in a drop of water or dilute glycerine. Whenever fresh specimens of fish were available, the required scales were removed before putting the fish in the preservative. For decalcification, Hydrochloric acid, Jenkin's decalcifying and dehydrating fixative, and Ziegler's solution, gave satisfactory results. Sections of non-decalcified scales embedded in celloidin-paraffin or simply in hard paraffin, were preferred to those of the decalcified ones. Ground sections were prepared by the method recommended by Bhatti (1938). The extent of calcification and the structure of ctenia in ctenoid scales were studied by washing the scales in distilled water, then placing them in 1 % solution of Silver Nitrate and exposing them to direct sunlight for about two minutes. The calcified portions turned black and the non-clacified portions remained colourless (Fig. 15). Scales were also treated with 10 % solution of Potassium Hydroxide, with the result that the uncalcified portion got dissolved leaving only the calcified portion.

## FISHES STUDIED

Scales of the following freshwater and marine teleost fishes have been studied :

Order PHYSOSTOMI

Family **Cyprinidae**

Genus LABEO Cuvier

*L. rohita* (Ham.); *L. calbasu* (Ham.); *L. gonius* Ham.

Genus CIRRHINA (Cuvier) Oken

*C. mrigala* (Ham.); *C. reba* Ham.

Genus CATLA Cuv. & Val.

*C. catla* (Ham.).

Genus BARBUS Cuv. & Val.

*B. (Tor) putitora* (Ham.); *B. (Puntius) sarana* (Ham ); *B. (Puntius) chrysopterus* (McClelland) Day

Genus CARASSIUS Nilsson

*C. auratus* L.

Family **Notopteridae**

Genus NOTOPTERUS Lacepede

*N. notopterus* (Pallas); *N. chitala* (Ham.)

Order ACANTHOPTERYGII

Family **Ophicephalidae**

Genus OPHICEPHALUS Bloch

*O. marulius* Ham. ; *O.striatus* Bloch ; *O. punctatus* Bloch ; *O. gachua* Ham.

Family **Anabantidae**

Genus ANABAS Cuvier

*A. scandens* Dald.

Family **Osphronemidae**

Genus COLISA Cuv. & Val.

*C. fasciata* (Bl. & Schn.)

Family **Sciaenidae**

Genus SCIAENA Cuvier

*Sciaena* sp.

HISTORICAL

Owen (1866), in his "Anatomy of the Vertebrates", has given an illustrated description of the scales of some teleosts, and has made a clear distinction between cycloid and ctenoid scales. This distinction, though convenient, has frequently been challenged. Bridge (1904), for example, has pointed out that some teleosts possess scales which are neither cycloid nor ctenoid, but are intermediate in form between the ordinary

teleost scales and the dermal denticles. Merriman's (1939) work on the scales of *Elops saurus* has, similarly, lead him to discuss the inadequacy of the terms 'cycloid' and 'ctenoid'.

The nature of the scale parts, such as the spines of the ctenoid scales, the circuli or the calcareous depositions, has been discussed among others by Tims (1905), Cockerell (1911), Bhatti, (1938) and Pritchard (1940). A great deal of confusion has been caused in the literature by an indiscriminate and loose usage of the terms.

The ontogenetic development and regeneration of the scales as a whole, or their various parts, have been studied by Setna (1934), Bhatti (op. cit.), Fowler (1935), Marshall (1939), Prashad, Hora & Nair (1940), Neave (1940, '43), Ganguly & Mookerjee (1947) and numerous other workers.

Similarly, the applied aspects of scale-development, i.e., the determination of the age of the teleost fishes by scale reading, has also been explored by workers too numerous to mention, though the fishes studied have, in most cases, been the common food fishes.

## Order PHYSOSTOMI

### Family CYPRINIDAE

The scales, in general, are very thin and are all cycloid. Both circuli and radii are very fine. The radii, except in the case of *Cirrhina reba*, run in all directions. The base and the basal circuli are more or less undulate.

### Genus ***Labeo*** Cuvier

#### ***Labeo rohita*** (Ham.)

† L. l. = 40-42 ; L. tr. = 6½/9 ; L. b. = 4 : 3 ; L. s. l. f. = 1 : 16. 1.

*Scale* sub-quadrate, with more or less straight sides running almost parallel to each other (Fig. 1); apex sharply curved ; base undulated. *Nucleus* lying a little distance basad *of the middle. *Circuli* very fine and replaced in the apical field by tubercles ; some of the circuli, however, entering the sides of the apical field unmodified. The circuli in the lateral quadrants more widely spaced and also a bit broader than those in the basal quadrant. The circuli finely denticulated, the denticles being indistinct in the lateral ones. *Radii* running in all directions. Basal

† *L. l.* number of latinucleate scales ; *L. tr.* number of scales in transverse series ; *L. b.* ratio between length and breadth of scale; *L. s. l. f.* ratio between length of scale and standard length of fish.

* Basad implies position of the focus or nucleus of a scale towards the base in relation to the middle of the scale, (Cockerell, 1912).

radii about sixty in number, crowded together at some places and some of them branching several times centripetally, while others incomplete and only a few starting from the nucleus proper. Lateral radii about twenty three in number, running almost parallel to one another and therefore not all starting from the nucleus. Lateral and apical radii more or less intergrading, there being no sharp line of demarcation between the two sets. Apical radii about ten in number, with lines of prominent tubercles running in between them. About forty one radii, all vertical in direction in the posterior half of the apical field.

### *Labeo calbasu* (Ham.)

L. l. =40-44 ; L. tr. =7½-8 ; L. b. =7 : 5 ; L. s. l. f. =1 : 8.2.

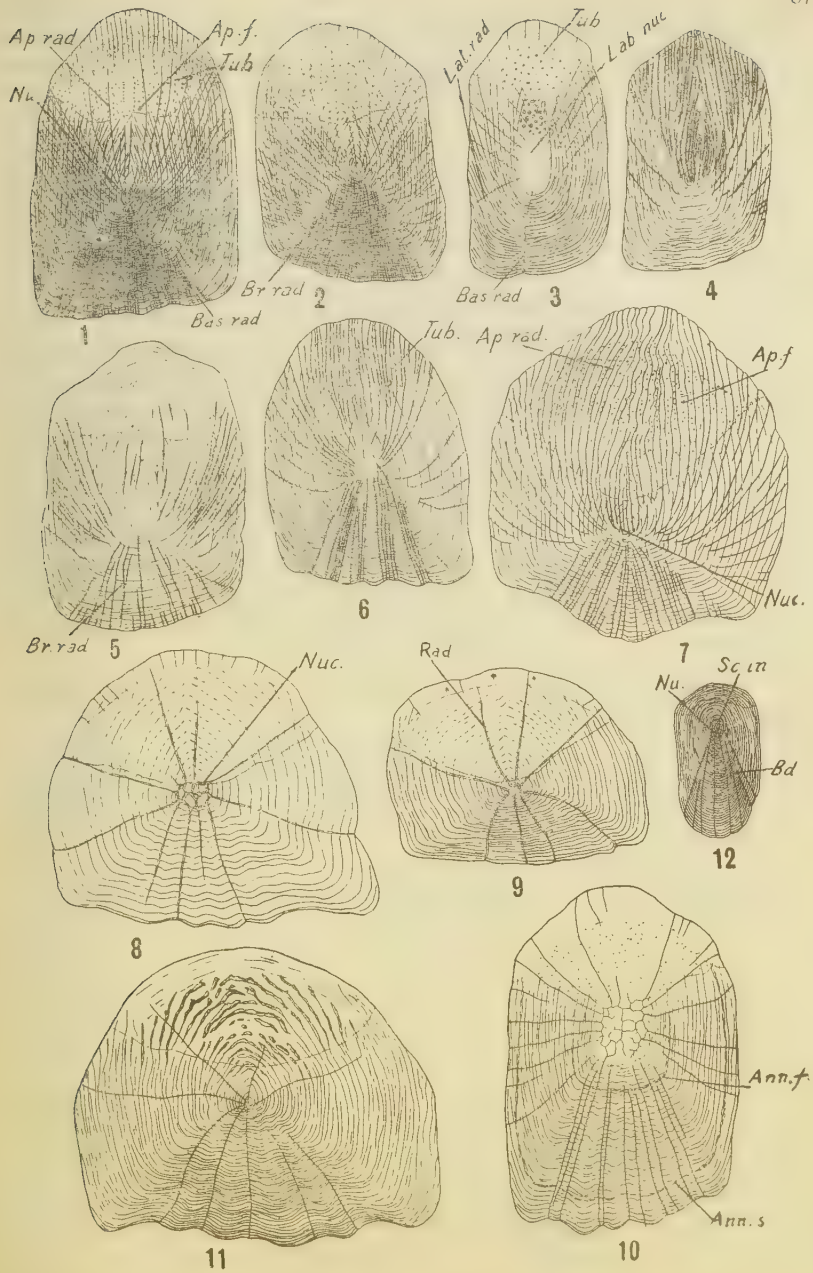
*Scale* more or less rhomboidal (Fig. 2), the sides roughly parallel and straight. *Nucleus* basad of the middle. *Circuli* fine and gradually

EXPLANATION OF FIGURES

The following letters and numerals have been used in the following account to indicate the exact position of the scale on the body of the fish.

L1. : from transverse series, from left side ;
L2. : from behind the left operculum, below the lateral line ;
L3. : from antero-lateral angle of left pelvic fin ;
L4. : from lateral line, on the left side ;
L5. : from below the dorsal fin, one the left side ;
R1. : from transverse series, from right side ;
R2. : from behind the right operculum, below the lateral line ;
R3. : from antero-lateral angle of right pelvic fin ;
R4. : from lateral line, on the right side ;
R5. : from below the dorsal fin on the right side.

Fig. 1. Scale of *Labeo rohita*, showing distribution of radii in all directions, branching of some of the basal radii, and tubercles in the apical field (L1.), x 2.5. Fig. 2. Scale of *L. calbasu*, showing uniform distribution of basal radii (R1), x 2.5. Fig. 3. Scale of *L. gonius*, showing fewer radii (L1), x 4. Fig. 4. Scale of *Cirrhina reba*, showing absence of basal radii and extensive development of apical radii (L1), x 2.5. Fig. 5. Scale of *Cirrhina mrigala*, showing some branching basal radii, evanescent circuli near the apical margin, and lines of tubercles in the apical field (L1), x 4. Fig. 6. Scale of *Catla catla*, (R1), x 2.5. Fig. 7. Scale of *Barbus (Tor) putitora*, showing zigzag course of the apical radii, and position of nucleus near the base (R1), x 4. Fig. 8. Scale of *Barbus (Puntius) chrysopterus*, showing notched margin, wavy basal circuli, tubercles in the apical field and regenerated nuclear region (R1), x 9. Fig. 9. Ontogenetic scale of *Barbus (Puntius) chrysopterus*, showing few radii and small nucleus (R2), x 9. Fig. 10. Scale of *Barbus (Puntius) sarana*, showing annuli of two successive winters and regenerated nucleus with anastomosed radii (L1), x 4. Fig. 11. Scale of *Carassius auratus*, showing ctenoid tendency (L1), x 11. Fig. 12. Scale of *Notopterus notopterus*, showing the inset scale near the subapical nucleus, broad apex and coarse beads (R1), x 78.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transforming into tubercles in the apical field. Basal circuli more deeply spaced and finely beaded. *Radii* numerous and running in all directions. Basal radii about sixty in number as in *L. rohita*, but unlike the latter more or less evenly distributed. Some of the basal radii branched. Lateral radii about sixteen on each side, most of these incomplete, running obliquely upwards, and not all of them beginning from the nucleus. Apical radii about twelve in number, but only three or four complete. In the posterior margin about twenty radii occuring in between others.

***Labeo gonius*** (Ham.)

L. l. = 71-84 ; L. tr. = 16/17 ; L. b. = 11 : 6 ; L. s. l. f. = 1 : 24. 1.

*Scale* oblong (Fig. 3), sides straight and slightly tapering towards the apex, base slightly oblique and apex sharply curved. *Nucleus* labyrinthiform, with irregular and broken marks and not well-defined. The central area of the scale showing various markings. *Circuli* very fine, generally very irregular and much broken, some of them anastomosing with others ; replaced in the apical field by thinly distributed round tubercles. In the basal quadrant the circuli very finely beaded. *Radii* running in all directions, very few in number, most of them broken up and incomplete. The basal radii about six in number, but may be absent in some scales. The lateral radii also about six in number on each side. Apical radii three or four.

The genus *Labeo* and its three species are identifiable on the basis of scale characters as follows :

Scales cycloid, subquadrate or oblong, distinctly longer than broad, circuli fine, replaced at apical field by fine or coarse tubercles ; lateral radii almost parallel and not starting from focus .....***Labeo***

Scales sub-quadrate, apex sharply curved ; basal radii crowded at places, lateral radii twenty three, almost parallel, apical radii ten, with prominent tubercles between them .....*L. rohita*

Scale more or less rhomboidal, apex broadly rounded, basal radii numerous, evenly distributed, lateral radii eighteen on each side, most of them incomplete, apical radii twelve, three or four complete ..... .....*L. calbasu*

Scale oblong, apex sharply curved ; nucleus not well-defined ; circuli in the apical field replaced by rounded tubercles ; basal radii few or absent, lateral and apical radii few.....*L. gonius*

Genus ***Cirrhina*** (Cuvier) Oken

The scales resemble those of *Labeo*, except that the radii are fewer.

### *Cirrhina mrigala* (Ham.)

L. l. =40-45 ; L. tr. =7-8½ ; L. b. = 10-7 ; L. s. l. f. =1 : 16. 6.

*Scale* very thin, roughly ovoid (Fig. 4), its sides curved and slightly converging towards the apex, the base curved centrifugally, the apical margin smooth and produced into an obtuse angle, with the ultimate apex blunt. *Nucleus* distinctly basad of the middle. *Circuli* very fine and replaced in the apical field by tubercles, the transition being very distinct. At the posterior end of the scale the tubercles replaced by rather evanescent or feebly developed circuli running parallel to the free margin of the scale. The basal circuli finely beaded, much broken, curved. *Radii* many, running in all directions. The basal radii about twenty five, only six or seven reaching the nucleus, others irregular in their development. Some radii confined to the base, while others midway between the base and the nucleus ; a few branching centripetally. The lateral radii about a dozen on each side, prominent, running obliquely upwards, some extending from the nucleus to the margin, while others situated midway between the two. The apical radii ten in number, showing the same irregularities in distribution as others.

### *Cirrhina reba* (Ham.)

L. l. =35-38 ; L. tr. = 7/9 ; L. b. = 16 :9 ; L. s. l. f. =1 : 15. 7.

*Scale* sub-quadrate, sides running parallel to each other, base slightly oblique and undulated, the apex curved into a more or less sharp angle (Fig. 5). *Nucleus* situated about one third the total length from the base. *Circuli* very fine, the basal ones distinctly beaded, the lateral ones widely spaced and running parallel to the sides. The apical circuli replaced by tubercles. *Radii* absent in the basal quadrant, lateral radii few in number, running obliquely upwards, the apical radii numerous, prominent, running right up to the free posterior margin.

The two species of *Cirrhina* can be discriminated on scale characters as follows :

Scales cycloid, subquadrate or ovoid ; circuli replaced at the apical field by tubercles ; radii many and running in all directions .....***Cirrhina***

Scale ovoid, apex smooth ; nucleus basad of the middle ; basal radii delicate, many, incomplete ; lateral radii many ; apical radii very few.....*C. mrigala*

Scale sub-quadrate, apex curved into a sharp angle ; nucleus about one third of the length from the base , basal radii absent or very few ;

lateral radii few ; apical radii many, vertical to the posterior free end of the scale ..... *C. reba*

Genus ***Catla*** Cuv. & Val.

***Catla catla*** (Ham.)

L. l. 50 = -43 ; L. tr. = 7½/9 ; L. b. = 4 : 3 ; L. s. l. f. = 1 : 14. 4.

*Scale* cycloid, ovoid in shape (Fig. 6), base oblique, wrinkled, attaining the maximum breadth near the middle ; apex smooth, rounded. *Nucleus* basad of the middle. *Circuli* fine, the basal circuli many, running parallel to the wrinkled base, much broken, sometimes distinctly beaded. Lateral circuli broader, more finely spaced, becoming still broader and discontinuous on reaching the apical field, producing elongated tubercles. The more central circuli and the lines of tubercles from the two sides in the apical quadrant meeting in an acute angle along the long axis. *Radii* running in all directions, much more numerous at the apex than elsewhere. The basal radii about twenty, some incomplete, distributed rather irregularly. The lateral radii about ten on each side, curved in the middle in the direction of the base of the scale. The apical radii forty, running up to the free posterior margin of the scale. The apical field relatively small.

Genus ***Barbus*** Cuv. & Val.

The scales of the three species of *Barbus* studied here have so little in common that there is little justification for the inclusion of these species in the same genus.

***Barbus (Tor) putitora*** (Ham.)

L. l. = 30 ; L. tr. = 4½/5 ; L. b. = 12 : 11 ; L. s. l. f. = 1 : 16. 1.

*Scale* sub-circular (Fig. 7), the two ends of the base curved centripetally, forming two notches near the anterolateral angles ; the middle portion of the base consequently produced into a broad and convex process. The sides also curved, attaining the maximum breadth of the scale at about the middle ; the apex wavy. *Nucleus* situated about one third the length of the scale from the base. The basal *circuli* strongly beaded and much broken, replaced in the apical quadrant by tubercles. The basal *radii* thirty five, many incomplete ; the lateral and apical radii 60 in number, prominent ; the two sets of radii intergrading in such a way as to render it difficult to distinguish the truly lateral radii except a few near the base. The apical radii, near the longitudinal axis of the scale, running in a zig-zag manner, reaching the posterior free margin, producing a wavy effect. The area of the apical quadrant lying near the nucleus having labyrinthiform markings in addition to the ordinary tubercles.

***Barbus (Puntius) chrysopterus*** McClelland

L. l. = 23-25 ; L. tr. = 5/5 ; L. b. = 12-13 ; L. s. l. f. = 1 : 12.

*Scale* dome-shaped, distinctly broader than long (Fig. 8), base, sides and apex wrinkled. *Nucleus* centrally placed. *Circuli* very fine, indistinctly beaded, basal ones corresponding to the wrinkles of the base. Lateral circuli meeting those of the opposite side along the long axis of the scale in a sharp angle. *Radii* running in all directions, very few, about two to four in each quadrant. With the exception of some minute ones, all the radii starting from the nucleus (Fig. 9), but some of them not reaching the margin of the scale.

***Barbus (Puntius) sarana*** Ham.

L. l. = 32-34 ; L. tr. = 6½/6 ; L. b. = 3 : 3 ; L. s. l. f. = 1 : 10.

*Scale* sub-quadrate (Fig. 10), sides more or less parallel and straight, base prominently scalloped, apex round and smooth. *Nucleus* distinctly apical, situated about one fifth the total length from the base. Basal *circuli* more prominently developed than the lateral ones and corresponding to the curvature of the base, running parallel to it and beaded. Lateral circuli fine and running parallel to the side. Apical field free from circuli, the latter being replaced by rounded tubercles. The tubercles leaving a broad border at the apical margin free. *Radii* running in all directions, about ten radii in the basal quadrant, about six lateral radii on each side and about ten apical. The annuli are very well developed in the scales of this fish, showing that the fish, when caught, was in the early part of its third year.

The three species studied possess the following distinguishing characters :

Scale sub-circular, base curved centripetally, forming two notches near antero-lateral angles, apex wavy ; basal circuli strongly beaded and much broken, replaced by tubercles; in apical field the lateral radii merging into apical radii, numbering about 60, apical radii extending to the posterior free margin, and central ones running in a zig-zag manner..... .....*B. (Tor) putitora*

Scale dome-shaped, slightly broader than long, apex wrinkled ; nucleus central; basal circuli wavy, apical ones much broken; radii running in all directions, very few.....*B. (Puntius) chrysopterus*

Scale more or less rectangular, longer than broad, scalloped base, apex sharply curved ; nucleus subapical ; basal circuli wavy, apical one replaced by tubercles ; basal radii about a dozen, lateral radii running obliquely, apical radii only a few.....*B. (Puntius) sarana*

Genus ***Carassius*** Nilsson

***Carassius auratus*** L.

L. l. = 29 ; L. tr. = 6½/7 ; L. b. = 10 : 11 ; L. s. l. f. = 1 : 16.6.

*Scales* similar to those of *Barbus (Puntius) chrysopterus* but the sides more or less evenly curved and without any notches (Fig. 11). *Circuli* thicker, more widely spaced, very few in the apical field ; the ends of circuli more or less pointed and raised, giving the scale a poorly developed ctenoid tendency.

Family NOTOPTERIDAE

Genus ***Notopterus*** Lacepede

***Notopterus notopterus*** (Pallas)

L. l. = 225-259 ; L. tr. = 29-45/40-55 ; L. b. = 17 : 10 ; L. s. l. f. = 1 : 68.8.

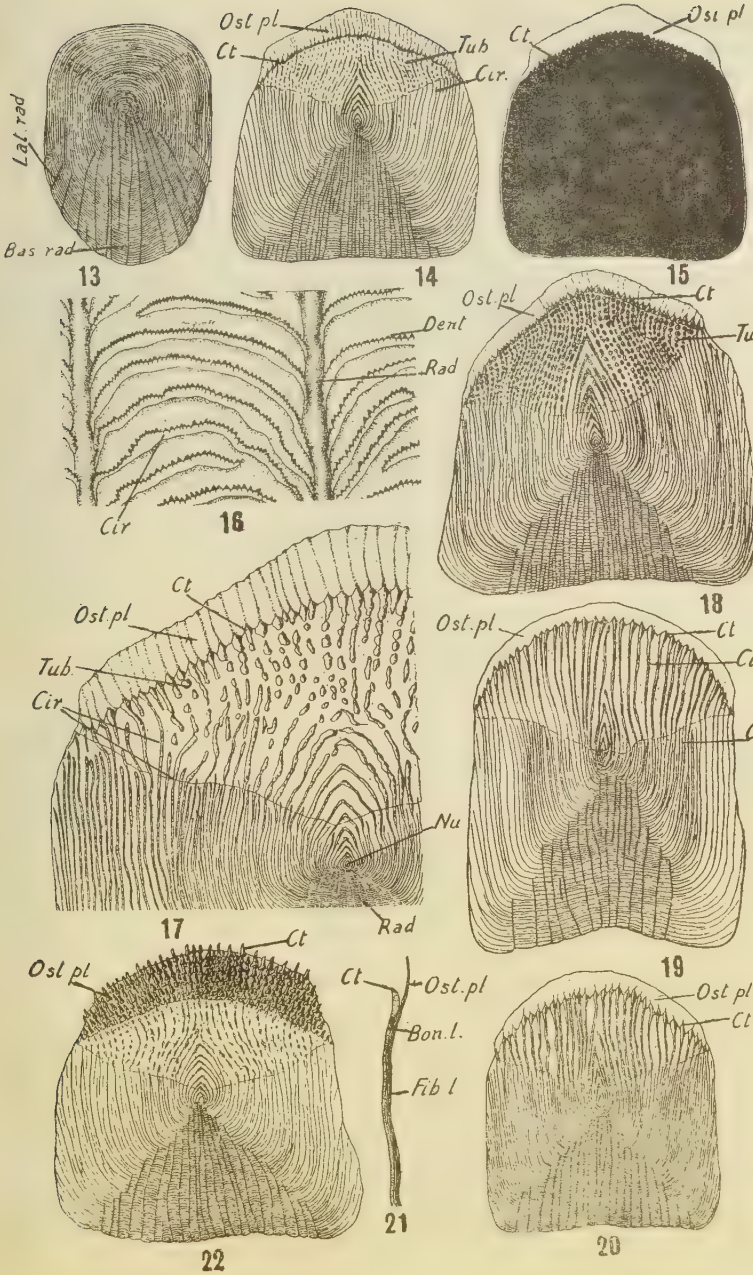
*Scale* obovate and cycloid (Fig. 12), apical region broadest, apex broadly rounded, margin smooth, sides gradually tapering towards the base, which is rounded. *Nucleus* situated about two seventh the length from the apex. *Circuli* regular, running all round uninterrupted except in the region of the radii, parallel to the sides, strongly beaded in the nuclear region, the beads continuing in the basal quadrant up to half the distance. The extent of the development of the beads inversely proportional to the distance from the nucleus. In the apical quadrant minute and sparsely distributed beads present on the circuli near the nucleus. *Radii* only basal, about eight in number, the outer ones complete or incomplete, meeting the base and producing slightly scalloped effect. In some scales almost all the radii reaching the nucleus.

***Notopterus chitala*** (Ham.)

L. l. = 180-200 ; L. tr. = 21-25/34-37 ; L. b. = 22 : 15.2 ; L. s. l. f = 1 : 66.

*Scale* obovate and cycloid (Fig. 13) ; sides roughly parallel to each other in the posterior half of the scale, gradually tapering in the anterior

Fig. 13. Scale of *Notopterus chitala*, showing broad apex, subapical nucleus, basal and lateral radii (R1). x 78. Fig. 14. Scale of *Ophicephalus marulius*, showing ctenoid area, osteoid plate and lines of tubercles (L1), x 4. Fig. 15. Scale of *O. marulius*, treated with silver nitrate, showing uncalcified osteoid plate, x 4. Fig. 16. Highly magnified view of a portion of a scale of *O. marulius*, showing radial furrows, centripetally curved circuli, discontinuation of circuli at the radii, and prominent denticles developed on the circuli, with the pointed ends directed towards the nucleus, x 180. Fig. 17. Portion of scale of *O. marulius*, showing transition of circuli to ctenia, x 125. Fig. 18. Scale of *O. striatus*, showing prominent tubercles and ctenia (L1), x 4. Fig. 19. Scale of *O. punctatus* (R 1), x 8. Fig. 20. Scale of *O. gachua* (L 1), x 8.8. Fig. 21. Longitudinal section of the posterior portion of a non-decalcified scale of *O. marulius*, showing the relation of ctenium with the osteoid plate and the bony and fibrillary layers of the scale. Fig. 22. Scale of *Anabas scandens*, x 8.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half ; apex smooth and more or less flattened, the base rounded and slightly scalloped. *Nucleus* well defined, apical (or towards the apex in relation to the middle of the scale), about one third of the scale from the apex. *Circuli* fine and complete except at the radii, running parallel to the sides, more or less closely spaced at the apex, not beaded. *Radii* present in the basal half of the scale, about eighteen in number and only the central ones reaching the nucleus.

The two species are readily separable on scale characters.

Scale obovate, cycloid, apex broadly rounded and smooth ; nucleus about two seventh from base; circuli regular, beaded in the central and apical regions; radii basal, about eight, almost all reaching the nucleus... .....*N. notopterus*

Scale obovate, cycloid, apex smooth and flattened ; nucleus apicad to the middle of the scale ; circuli fine, complete, not beaded ; radii basal, about 18, outer ones not reaching the nucleus.....*N. chitala*

## Order ACANTHOPTERYGII

### Family OPHICEPHALIDAE

### Genus ***Ophicephalus*** Bloch

#### ***Ophicephalus marulius*** (Ham.)

L. l =56-70 ; L. tr. =4½-6½/13-11 or 5½-8½/13-11 ; L. b. =1 : 1 ; L. s. l. f. =1 : 35.

*Scale* sub-quadrate (Fig. 14), sides slightly tapering both anteriorly and posteriorly, the maximum breadth being attained near the middle of the scale, base wrinkled due to numerous radii, apex wavy. *Nucleus* a little distance apicad of the middle. *Circuli* prominently developed, strongly beaded or denticulated, with pointed apices, directed towards the nucleus of the scale (Fig. 16). The segments of the basal circuli lying in between the radii curved centripetally. The denticles or beads more prominent in the central region where the circuli are developed. In the basal quadrant the number of circuli twice as many as in the lateral quadrants. The lateral circuli thicker, more widely spaced (Fig. 14), meeting the lateral margin of the scale in an oblique manner ; the more central circuli becoming thicker on reaching the apical field, but some of them getting discontinued. The apical circuli starting from the nucleus and converging towards the long axis, the more central ones meeting the fellows of the other side (Fig. 17), but changing their course a little distance from the osteoid plate and ending in pointed structures or ctenia. The circuli moniliform. *Radii* basal, about thirty five in number ; only a few ventral

ones continuing up to the nucleus, others ending at the junction of the basal and lateral quadrants.

### *Ophicephalus striatus* Bloch

L. l. = 20-57 ; L. tr. = 4½-7/9 or 5½-8/10-9 ; L. b. = 1 : 1 ; L. s. l. f. = 1 : 32.

*Scale* roughly like that of *O. marulius*, but the breadth maximum near the base (Fig. 18), sides tapering towards the apex ; base slightly wrinkled corresponding to the radii. The osteoid plate comparatively narrower, its free margin wavy. *Nucleus* centrally placed. *Circuli* prominently developed, the portions of the basal circuli in between the radii being curved centripetally ; the basal circuli more densely crowded but narrower than the lateral ones. The circuli of the basal quadrant strongly beaded, the extent of development of the beads being directly proportional to the distance of the circuli from the base. The beads denticulated with pointed apices. The lateral circuli, on reaching the anterior margin of the apical field, taking up a moniliform appearance. As in *O. marulius*, the lateral circuli near the centre converging towards the long axis of the scale, the outer ones diverging to ctenia. *Radii* about 37, in the basal quadrant, running more or less parallel to one another, only the central ones reaching the nucleus.

### *Ophicephalus punctatus* Bloch

L. l. = 37-40 ; L. tr. = 4-5/9 or 9/6 ; L. b. = 4 : 3 ; L. s. l. f = 1 : 18.25.

*Scale* sub-quadrate (Fig. 19), base wrinkled and centripetally curved, sides roughly parallel to each other, apex broadly rounded. The osteoid plate prominent. *Nucleus* sub-apical. The basal *circuli* very densely crowded, finely beaded, beads being denticulate ; the lateral circuli widely spaced, running vertically upwards, parallel to the long axis, becoming much thicker in the apical field and ending uninterrupted in feebly developed ctenia. *Radii* all basal, irregularly distributed, about twenty one in number, many of them not reaching the base at all.

### *Ophicephalus gachua* Ham.

L. l. = 40-45 ; L. tr. = 3-4/7-6 ; L. b. = 1. 1 : 1 ; L. s. l. f. = 1 : 20.

*Scale* sub-quadrate, with more or less flat and wrinkled base (Fig. 20), sides parallel to each other, apex like a semicircle, the angle produced by the sides and base about 90°on each side. The osteoid plate broad. *Nucleus* more or less central. *Circuli* densely crowded in the basal quadrant and finely beaded, the segments intersected by the radii curved centripetally. In the central area the minute beads replaced by comparatively coarse beads. The lateral circuli running parallel to the long axis as well

as to the sides, some of them getting discontinued on reaching the anterior margin of the apical field, others lying in between them, entering the apical field and becoming thicker, finally ending in pointed and rather feeble ctenia. *Radii* about 21 in number, more regular than in *O. punctatus*, running parallel to each other, only the central ones extending up to the nucleus.

Day (1876) observes that among Ophicephalidae, "the different species are somewhat difficult to distinguish from one another, owing to their similarity in colour, the change of livery according to age and locality, and the slight variation in the number of fin rays and scales." The present investigation however shows that the scale characters may satisfactorily be made use of in discriminating the four species of the family studied.

1. Scale ctenoid, as long as broad, base more or less straight, sides converging towards the apex and symmetrical, apex making a distinct angle, ctenia prominent.

   A. Circuli at the apical field broken up into coarse tubercles, at first converging towards the long axis, and then running towards the posterior margin perpendicularly.

      (a) Scale more or less symmetrical on both sides of the long axis, maximum breadth near the middle ; osteoid plate one-ninth the total length of the scale.....*O. marulius*

      (b) Sides of the scale distinctly asymmetrical, maximum breadth

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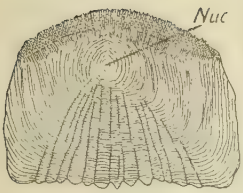
Fig. 23. Scale of *Colisa fasciata*, x 11. Fig. 24. Portion of a scale of *Colisa fasciata*, showing transition of circuli to ctenia, and branched circuli, x 24. Fig. 25. Body scale of *Sciaena* sp., showing primary and secondary lines of ctenia, x 12. Fig. 26. A portion of scale of *Sciaena* sp., magnified, showing widely spaced circuli near the broadened nucleus and primary and secondary lines of ctenia, x 34. Fig. 27. Head scale of *Sciaena* sp., showing strongly and uniformly developed ctenoid area and absence of radii, x 34. Fig. 28. Regenerate scale of *Ophicephalus marulius*, showing regenerated wide nucleus, x 4. Fig. 29. Regenerate scale of *Sciaena* sp., showing re-appearing ctenia. Fig. 30. Regenerate scale of *Barbus (Puntius) chrysopterus*, showing a system of anastomosed radii in the central area, and also greater number of radii developed outside (L1), x 9. Fig. 31. Ontogenetic scale of *Catla catla* (L2), x 2.5. Fig. 32. Regenerate scale of a young *Catla catla*, showing labyrinthiform nucleus and greater abundance of radii (R1), x 4. Figs. 33-36. Scales of Ophicephalidae from near the opercula, showing oblique and curved bases. Fig. 33. *O. marulius* (L2), x 8. Fig. 34. *O. striatus* (R3), x 8. Fig. 35. *O. punctatus* (R2), x 8. Fig. 36. *O. gachua* (R2), x 8. Fig. 37. Scale of *O. striatus* from the antero-lateral angle of pelvic fin showing deformed posterior region (R3), x 8.

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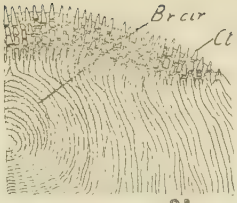


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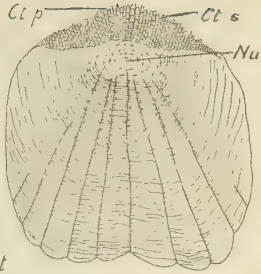


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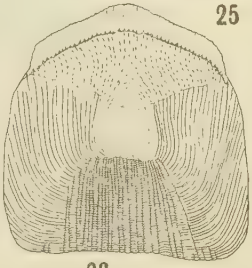

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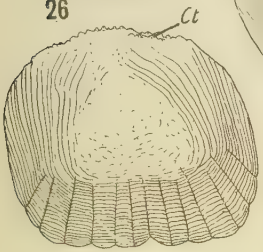


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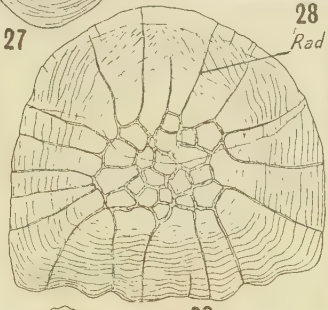


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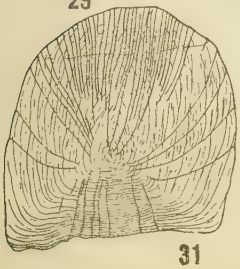

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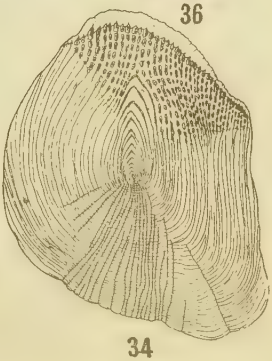

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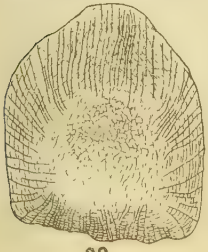

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near the base; osteoid plate one-twenty-second the total length of the scale.....*O. striatus*

2. Scales longer than broad, base curved towards the centre, sides parallel, apex dome shaped in the form of a semi-circle, ctenia feeble.

B. Circuli at the apical field running uninterrupted vertically upwards without showing any noticeable convergence.

(a) Nucleus sub-apical, osteoid plate one-twenty-fifth the total length of the scale.....*O. punctatus*

(b) Nucleus more or less central, osteoid plate one-fifteenth the total length of the scale..... .....*O. gachua*

Genus ***Anabas*** Cuv.

***Anabas scandens*** Dald.

The scales so closely resemble those of *O. marulius* or *O. striatus* that their description may apply very well in this case. The only remarkable distinction is that in the scales of *A. scandens* each of the circuli in the apical field ends in many denticles (ctenia). The row of denticles crosses the osteoid plate and the last ones project beyond the posterior free margin (Fig. 22). Radii are about twenty six in number. In a large scale from the same specimen, the number of radii was found to be twenty-nine.

Family OSPHRONEMIDAE

Genus ***Colisa*** Cuv. & Val.

***Colisa fasciata*** (Bloch & Schn.)

L. l. = 25-31 ; L. tr. = 4½-5½/11-13 ; L. b. = 5 : 6 ; L. s. l. f. = 1 : 17.

*Scale* sub-quadrate (Fig. 23), typically ctenoid, sides roughly parallel to each other, apex broadly rounded, the ultimate ctenia projecting beyond the free margin. *Nucleus* sub-apical, situated within one-third the total length from the apex. *Circuli* fine, very densely spaced in the basal quadrant. The segments of circuli lying between two radii curved centripetally. Basal circuli very finely beaded ; the lateral circuli less dense and widely spaced towards the apex. In and around the nucleus, the circuli giving off minute branches on both sides in a characteristic manner (Fig. 24). About a dozen circuli, starting from the nucleus towards the apex, are seen to be complete ; after that the circuli get thicker, run a little way perpendicularly to the free posterior margin and then become transversely segmented to form three ctenia each. At the sides, the

circuli segment to form one or two ctenia, while at the extreme side they do not segment at all. This unsegmented condition of the ctenia at the extreme sides is found in *Anabas scandens* also, and reminds one of the unsegmented ctenia in the species of Ophicephalidae. Basal *radii* sixteen in number, the central ones extending up to the nucleus. The radii meeting the base, producing a scalloped appearance.

Family SCIAENIDAE

Genus ***Sciaena*** Cuv.

***Sciaena*** sp.

*Scale* rhomboidal (Fig. 25), deciduous, base wrinkled, sides oblique, running parallel to each other; apex ctenoid, tne ctenoid area comparatively small. *Nucleus* sub-apical, one-fifth the total length of the scale from the apical margin. In the nuclear region the circuli complete, very widely spaced, in other regions densely distributed. *Circuli* very fine, basal ones finely beaded. The initial ctenia very broad as compared to the circuli near the apical field, apparently using up all the available circuli-forming material. Consequently in this region circuli fail to maintain their identity and do not show a clear transition into ctenia. The ctenia get bigger and bigger, in both length and breadth, as they reach the apical free margin; one or two secondary lines of ctenia are seen to originate in the space between two primary lines of ctenia (Fig. 26). The number of ctenia is maximum along the longitudinal axis of the scale, where as many as nine or ten ctenia are found in the same line; the number goes on decreasing towards both the sides away from the long axis, until only one ctenium is found to occur in a line. The ctenia can also be counted obliquely. *Radii* confined to the basal region only; no demarcation between the basal and lateral radii. Radii usually about ten but the number much larger in regenerate scales.

Head scales very small, without any radii (Fig. 27), obovate, ctenoid. Ctenoid area of uniform thickness, the number of ctenia in a line uniform throughout. On each side of the apical field there is an area which is free from ctenia. Ganguly & Mookerjee (1947) describe the head scales of *Sciaena coitor* Ham., to be typically cycloid, with no radii or ctenia. In *Sciaena* sp. studied, the head scales are free from radii, but they possess ctenia, the deposition of which is different from those on the body scales.

MORPHOLOGY OF SCALES

The scales, according to their position on the body, undergo different modifications in size, shape and character. Scales near the operculum

are comparatively broader than others and have their bases oblique (Figs. 33-36), while those from the region of the pelvic fins show their posterior field greatly deformed due to the movements of the fin (Figs. 37-40). Scales on the lateral line are usually traversed by the lateral line canal, which may or may not cause perforations in the scales (Figs. 41-44). Scales from near the dorsal fin are much narrower (Figs. 45-48), and those from the tail region are reduced in size. Head scales, when present, also show great variations. Individual scales vary in the number of circuli, radii and other essential features. This necessitates the examination of several scales from different regions on the same individual.

All the scales appear in the young as a small area, represented in the ontogenetic or normal scale by a central region, variously termed nucleus, focus,centre or centrum. The outer or superior side of the scale is variously sculptured, while the inner surface is more or less smooth. This sculpture takes the form of circuli, sclerites or ridges, and is of great taxonomic importance. The circuli are often intercepted by radial furrows known as radii, which generally extend from the focus to the periphery in radial directions.

*Focus, nucleus* or *centrum.* The nucleus, or the central area of a normal scale, is generally without any distinct circuli or radii and is usually covered with irregular, broken markings (Fig. 23). In grown up specimens its position may vary from species to species. Thus in *Barbus (Puntius) sarana, Colisa fasciata* and *Sciaena* sp., the nucleus is apicad to centre of the scale; in *Ophicephalus striatus,* it is in the middle, while in *Barbus (Tor) putitora* and *Cirrhina mrigala,* it is basad of the middle of the scale.

Occasionally a condition is found that may be interpreted by assuming that in these cases the young scale becomes dislocated in its pocket and rotates through an angle. Subsequent development being normal, there appears a large scale with a small one inset, the two with nuclei at different positions and main axes making an angle with each other (Fig. 12). Oosten (1928) also recognizes this condition.

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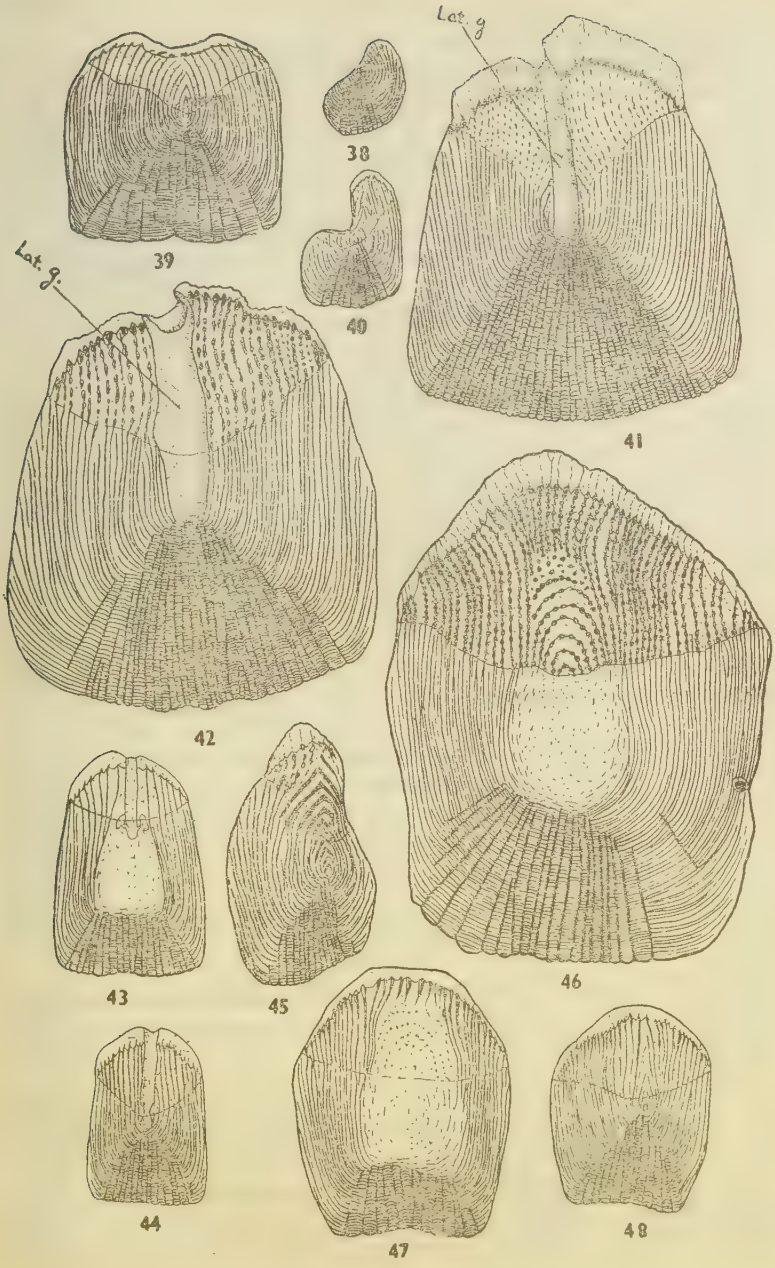
Figs. 38-40. Scales of Ophicephalidae, from antero-lateral angle of pelvic fins, showing deformed posterior region. Fig. 38. *O. marulius* (R3), x 8. Fig. 39. *O. punctatus* (L3), x 8. Fig. 40. *O. gachua* (R3), x 8. See also Fig. 37 for comparison. Figs. 41-44. Latinucleate scales of Ophicephalidae. Fig. 41. *O. marulius* (R), x 8. Fig. 42. *O. striatus* (R4), x 8. Fig. 43. *O. punctatus* (R4), x 8. Fig. 44. *O. gachua* (R4). Figs. 45-48. Scales of Ophicephalidae from near the dorsal fin. Fig. 45. *O. marulius* (R5), x 8. Fig. 46. *O. striatus* (L5), x 8. Fig. 47. *O. punctatus* (R5), x 8. Fig. 48. *O. gachua* (R5), x 8.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*Circuli, sclerites* or *ridges-*. The circuli, often referred to as sclerites or ridges, arise as elevations of the osteoid marginal area when the growth of the scale pocket is rhythmically arrested. They usually increase in height during the process of calcification (Neave, 1940). In cases where radii are present, the circuli are discontinuous along the radii (Figs. 17, 24). The circuli are not always circular in shape. In Notopteridae (Figs. 12,13), they typically encircle the nucleus, but in many other cases they show more or less vertical orientation in the apical field. In *Ophicephalus marulius* (Fig. 14), *O. striatus* (Fig. 18), *Barbus (Tor) putitora* (Fig. 7), and *Cirrhina mrigala* (Fig. 5), the circuli at the apical field are replaced by lines of tubercles.

*Denticles* or *beads-*. Cockerell (1912) describes scales of some fishes which have beaded basal circuli. Neave (1940) also recognizes this fact and says that at their full development the free edges of the sclerites (or circuli) present a beaded appearance. Bhatti & Islam (1951) also observe that the basal circuli in scales of *Ophicephalus gachua* are provided with minute denticles. In the scales of all the specimens studied, with the exception of *Notopterus chitala*, the circuli show some bead-like or denticulate structures on them. These are found to be quite prominent in the anterior covered portion of the scale. They are less prominent or feebly developed at the centre, and at the sides in the apical region they seem to be absent. They are prominent on fully grown circuli.

Cockerell (1912) mentions that the circuli of *Notopterus* are not beaded. The present investigations, however, show that although beads are absent in *Notopterus notopterus* (Fig. 12), the circuli are beaded and the beads seem to have become locally aggregated to form somewhat coarse structures. In Ophicephalidae and Anabantidae each of the denticles or beads has a stout base with a pointed and dark head projecting towards the nucleus of the scale (Fig. 16).

It appears that in the Physostomi the beads are less prominent and almost rounded, whereas in the Acanthopterygii, they are prominent and denticulate.

*Radii-*. Neave (1940) holds that the formation of the radii usually begins as a defection in the margin of the young scale, which is continued during subsequent growth centrifugally. Ganguly & Mookerjee (1947) studied the development of scales of *Sciaena coitor*, and remarked that the radii generally develop in the posterior field and divide the circuli contripetally, starting from the periphery towards the focus. In the course

of the present investigations it has been found that in the scales of some fishes, namely *Labeo rohita* and *L. calbasu* (Figs. 1-2), the radii extend up to the margin, but many of them are incomplete. In certain other fishes as in *Cirrhina mrigala* (Fig. 4), the basal radii are seen to be of different sizes, some reaching the focus, others midway between the focus and the periphery, and still others confined just to the base. In these three fishes some of the basal radii are seen to give off branches a little away from the base.

Cockerell (1912) holds that in *Notopterus* the radii are all basal and only the central ones reach the nucleus. The present investigations however, show that in *Notopterus chitala* all the radii are not basal, some of them are certainly lateral. In some scales of *Notopterus notopterus* almost all the radii reach the nucleus.

The function of the radii is rather controversial. Until recently it was held by many authors that they are tubes for the conduction of lymph or some other fluid. But as the present study reveals, they are not designed for any such function since they are not tubular but are mere furrows. Neave (1940) regards the radii to represent lines of flexibility, permitting the scales to conform to the shape and movements of the body. Ganguly & Mookerjee (1947) hold the same view. They also observe that the more flexible the body is, the larger is the number of the radii on the scales. Had flexibility been the cause of the development of the radii, the latter should have developed in all directions on the body scales of almost all fishes. But as has been observed, some fishes, such as Ophicephalidae (Figs. 14, 18, 20) do not at all have any radii in the apical and lateral fields of the scale, while in the genus *Barbus* radii may be present all over the scale, running in all directions (Figs. 7, 8, 10). In *Cirrhina mrigala* (Fig. 4) the radii extend in all directions, but in *Cirrhina reba* (Fig. 6) they are absent from the basal quadrant. These two species of the same genus should not have shown such a great deviation if the development of the radii had been due to flexibility alone. The presence and absence of basal radii is of taxonomic importance, but Cockerell's method of discriminating species on the number of radii is not very satisfactory, because the number of radii may vary considerably even on scales of the same fish. Some scales may have twice or thrice as many radii as others taken from the same region of the body.

*Ctenoid scales-*. Norman (1931) maintains that cycloid and ctenoid scales are not so widely different and that the one type is linked up with the other by an almost complete series of intermediate stages. Norman

(1931), Cockerell (1943-47), and Ganguly & Mookerjee (1947), observe that both cycloid and ctenoid scales may develop on different parts of the body in the same fish. Cockerell (1912), describing the scales of typical Acanthopterygian fishes, remarks that the toothed or ctenoid feature appears to be derived from the longitudinal apical circuli, which become modified and segmented, the terminal segments especially taking the form of teeth. Kyle (1926), speaking of ctenoid scales, says that the edges of the scale may grow unequally and rows of small points then project from the surface, which when hard, are sharp and rough to touch.

The ctenoid scale, thus, owes its name to the development of spines or ctenia at its posterior uncovered portion. The structure and development of ctenia have been the object of great controversy. Tims (1905) holds that the spines of the scalelets, of which the upper bony layer of the scale is composed, are homologous with the ctenia. He says that if the spines present on the scalelets of *Gadus callarias* be more pronounced, and slightly more perpendicular in direction, we have the spines of ctenoid scales. He goes on to say that the ctenia on a ctenoid scale are present only in the posterior field in the same position as the spines of scalelets in the Cod. The early tendency to disappear in the anterior field, according to him, is probably due to imbrication. But in the fishes studied in the present investigations, the spines, also referred to as beads or denticles, when present, are most prominent on the anterior covered portion of the scales, a little distance from the nucleus. The circuli in the posterior uncovered portion may also present tuberculated appearance. Moreover, the pointed ends of the spines or denticles are directed away from the scale margin perpendicular to the course of the circuli, but the ctenia are always pointing towards the posterior free margin of the scale. It is therefore doubtful if the spines are homologous with the ctenia. Ganguly & Mookerjee (1947) studied the development of ctenoid scales in certain Indian fishes, and remark that there is no correspondence between the number of spines and the position of the successive circuli. They regard the formation of ctenia as independent of that of the circuli, though both, are derived from the same material. They further observe that it is difficult to conceive how Cockerell (1912) postulated the formation of ctenia from the longitudinal apical circuli. The present investigations, however, corroborate Cockerell's view, and show that the ctenia and the circuli, as well as the denticles or beads on the circuli, develop from the same material, and in the scales of *Ophicephalus marulius* (Fig. 17), *Anabas scandens* (Fig. 22) and *Colisa fasciata* (Fig. 24), one may very distinctly see how

the circuli at the apical field become transformed into ctenia. In Ophicephalidae there is, behind the osteoid plate, a regular row of ctenia followed by coarse nodules or tubercles which are just continuations of the circuli in the apical field. The continuation, being less prominent, gives the apex a tuberculated appearance. The transition from circuli to ctenia may be best observed in an unstained ontogenetic scale taken from the side of the body (Fig. 17). In the apical quadrant in *O. marulius* and *O. striatus*, the corresponding circuli from the side are seen to converge towards the long axis of the scale and meet each other. When the exposed apical field is reached, the circuli are seen to become thicker and thicker. Some of the circuli disappear at this stage, as if to make more space and material available for the thickening circuli. These thick circuli, at places, are less prominent, so that the whole apical field takes up a nodulated or tuberculated appearance. The tubercles finally end in ctenia, which are obviously the apical pointed ends of the circuli. In *O. punctatus* and *O. gachua*, however, the circuli do not change their direction and run vertically without any interruption (Figs. 19, 20). The exposed apical field, in all these fishes, feels rough to touch. A similar condition is observed in *Anabas scandens*, with the difference that the circuli in this case are segmented into several ctenia (Fig. 22).

Ganguly & Mookerjee (1947) based their conclusions on the development and structure of the scales of *Sciaena coitor*. The scales of *Sciaena* sp. show essentially the same shape and structure as in *S. coitor*. The scales show vertical orientation of the circuli, but the continuation with the ctenia is not seen clearly as there is a gap between the two structures. This is easily explainable. As has been seen in Ophicephalidae, where the circuli are thick and well developed, some of the circuli disappear after they leave the basal radial area, and still others do so when they reach the apical field, thus providing more material, as well as more space, for the remaining ones to get thicker and thicker and finally to give rise to the ctenia. In *Sciaena coitor* and *Sciaena* sp. the circuli are very fine so that when the ctenia, which are thick and wide, develop from them, the whole material available is used in their formation, and the circuli either develop very feebly or do not develop at all (Figs. 25, 27). The circuli and ctenia, therefore, develop from the same material, the latter arising from the former and the development of the ctenia being directly dependent on the availability of the material or indirectly on the extent of development of circuli.

*Osteoid plate*-. A thin membranous extension at the posterior free margin, which continues round the whole scale as a narrow margin, is often

present in most of the teleostean scales. Neave (1940), in gold fish, calls it 'osteoid plate' and says that its tissue is collagenous, and that in a rapidly growing scale a comparatively large osteoid plate is formed before any calcification occurs. The latter process begins in the oldest part of the scale and spreads towards the periphery. As long as scale growth continues, there is always a recognizable osteoid margin. Pillay (1951) recognizes this osteoid plate in scales of *Mugil speigleri* (Bleeker) as a narrow zone along the apical margin, which is very thin and delicate and often gets damaged while removing the scale from scale pocket.

*Scales in Ophicephalidae-*. The osteoid plate occasionally conceals the extent of calcification, and thus masks the true shape of the scale. In Ophicephalidae, for instance, the scales in their gross appearance may easily be mistaken to be cycloid because of the presence of the osteoid plate at their free posterior margin. Boulenger (1904), Goodrich (1909) and Cockerell (1912) hold that scales in this family are cycloid. Ahmad (1943) refers to the scales of *O. striatus* as cycloid, but the shape of scales in other species is not mentioned. Bhatti & Islam (1951) describe scales of *O. gachua* as not typical actinopterygian. Bhatti & Haque (1952) point out that scales in this family are ctenoid.

The extent of calcification in the scales of Ophicephalidae may be observed by treating a scale in 1% solution of Silver Nitrate in the sun, when the circuli and spines turn black and the osteoid plate remains colourless (Fig. 15). This indicates that the osteoid plate represents an uncalcified area. This is further confirmed by boiling the scale in 10% Potassium Hydroxide when the osteoid plate gets dissolved, revealing the ctenoid plate nature of the scale. When staind with Picro-indigo-carmine the osteoid plate stands out distinctly from the rest of the scale, taking a bright blue tint, while the scale takes a greenish blue shade. Orange-G also stains the osteoid plate differentially. When a scale treated with Silver Nitrate is left to dry, the osteoid plate shrinks and curls under calcified portion of the scale, thus demonstrating the ctenoid shape of the scale. Sections of non-decalcified scale also show the ctenoid nature of the scale (Fig. 21).

Boulenger (1904) observes that the Ophicephalidae are closely related to the Anabantidae, the latter differing from the former in possessing rays in parts of dorsal, anal and ventral fins, and in having the body covered with ctenoid scales. The present investigations show that the Ophicephalidae too possess ctenoid scales like their relatives the Anabantidae. The scales of *Anabas scandens*, in their appearance and even the minute details,

have been found to be similar to those of Ophicephalidae (Figs. 18, 21), except that in *Anabas* each circulus segments into many ctenia instead of remaining unsegmented as in the Ophicephalidae. In the scales of the Anabantidae the ctenia extend to the posterior free border due to the great development of the osteoid plate. According to Boulenger (op. cit.) these two related families overlap each other in their geographical distribution. Jordan (1905) says that the family "Ophicephalidae seems nearer the Labyrinthine fishes (Anabantidae) of which perhaps it is a degenerate descendant."

*Regenerate scales*-. The normally small and well defined focus or nucleus of a scale may be replaced by an expanded central area devoid of circuli and irregular in outline. Scales with such expanded centres are termed regenerate scales in contrast to ontogenetic ones which are normal and are present on the body of the fish from its young stages. The regenerate scales replace those that have been lost earlier by accident, and their central expanded focus represents the lost scale. In some regenerate scales the centre may be devoid of distinct circuli, which may appear granular as in *Ophicephalus marulius* (Fig. 28) and *Sciaena* sp. (Fig. 29). In these fishes radii are not present in the regenerated focus. Normal growth of circuli and radii, however, is resumed in subsequent growth after the loss has been repaired. In *Barbus (Puntius) chrysopterus* (Fig. 30), and *Barbus (Puntius) sarana*, however, the radii make a network of grooves in a regenerated focus. This has also been observed by Neave (1940) who carried out experiments on regenerated scales by removing some scales from a scale pocket, and then comparing the regenerate scale growing in the same vacated pocket with the original scale previously removed. He remarks that the ridge formation begins long before the regenerating scale approaches the original scale in size. The first formed ridges are usually short, irregular and widely spaced, and there is a gradual transition to the fully formed normal circuli or ridges. It has been observed, during the present investigations, that in regenerate scales there is a profuse development of radii outside the expanded nucleus (Figs. 9, 30, 31, 32).

*Classification of fishes based on scale characters*-. The importance of the study of scales in the classification of fishes has been pointed out by Goodrich (1907), Cockerell (1912) and Pillay (1951). Cockerell (op. cit.) observes that "In the case of *Carpiodes velifer*, I used scales from the fishes forming the basis of Judy's record for Boulder Country, Colorado, without making any study of the fishes themselves. I noted with surprise that they corresponded very well with the scales of the common goldfish. Dr Max

Ellis, going over the collection, has discovered that the specimens are in fact wild dark coloured examples of the goldfish, *Carassius auratus.*" The various species of Ophicephalidae, according to Day (1876), are difficult to distinguish beacause of their apparent similarity in colour and for slight variation in the number of fin rays and scales. But in the course of present investigations, it has been found that not only the four species of Ophicephalidae, but all the nineteen species of fishes studied, could be discriminated, to some extent, on their scale characters only.

In fact, taking all the different characters of the scales together, it is often possible, as has been observed by Cockerell (1943-47), " to classify a fish if we have no more than a single scale from the middle of the side, where the characters are best known."

In discriminating species of the different genera, the characteristic features, which have been found to give satisfactory results are: Number of latinucleate scales ; number of scales in transverse rows ; ratio between length and breadth of the scale ; shape of apex ; position of nucleus ; presence or absence of circuli ; extent of development of tubercles in the apical field ; number and distribution of lateral and apical radii ; and in the case of Ophicephalidae, the extent of osteoid plate.

## SUMMARY

1. A detailed study of the scales of nineteen species of teleost fishes, both freshwater and marine, belonging to six different families, namely Cyprinidae, Notopteridae, Ophicephalidae, Anabantidae, Osphronemidae and Sciaenidae, has been made.

2. Scales from the transverse series, lying just below the lateral line and the adjoining area are, in general, typical. Scales from other regions are more or less deformed.

3. Circuli are ridge-like elevations, and radii are furrow-like depressions. Circuli, except in Notopteridae, are finely beaded. In *Notopterus notopterus*, finer denticulate beads are replaced by much coarser beads, which seem to be aggregations of finer beads. In Physostomi the development of beads, spines or denticles on the scales is feeble, while in Acanthopterygii it is quite strong.

The denticles are confined chiefly to the basal quadrant and the extent of their development is inversely proportional to the distance from the nucleus.

4. In ctenoid scales the ctenia and circuli develop from the same substance and their development is interrelated. In the scales of *Ophice-*

*phalus marulius*, *Anabas scandens* and *Colisa fasciata*, the transition from the circuli to ctenia is clearly visible.

5. The scales of the four species of Ophicephalidae studied are ctenoid, but a broad uncalcified osteoid plate at the posterior end masks ctenoid nature of the scales. On scale characters the Ophicephalidae and Anabantidae are closely related.

6. Scales of *Barbus (Tor) putitora*, *Barbus (Puntius) chrysopterus* and *Barbus (Puntius) sarana* have nothing in common to justify their inclusion in the same genus *Barbus*. Scales of *Barbus (Puntius) chrysopterus* and *Carassius auratus* closely resemble each other.

7. In regenerate scales, nucleus is big and irregularly marked, and radii much more numerous than in ontogenetic ones. In some fishes, as in Ophicephalidae, the regenerated area is devoid of radii and in others, as in *Barbus (Puntius) chrysopterus*, the regenerated area is traversed by a system of anastomosing canals.

8. The size of the scale, except in very young specimens, maintains more or less a definite ratio with the size of the fish. Further, by the study of scale characters, it has been possible to classify the fishes studied.

## ABBREVIATIONS

*Ann. f.*:-Annulus of first winter ; *Ann. s.*:-annulus of second winter ; *Ap. f.*:-Apical field ; *Ap. rad.*:-Apical radius ; *Bas. rad.*:-Basal radius ; *Bd.*:-Bead ; *Bon. l.*:-Bony layer ; *Br. cr.*:-Branched circulus ; *Br. rad.*:-Branched radius , *Cir.*:-Circulus ; *Ct.*:-Ctenium ; *Ct. p.*:-Primary line of ctenia ; *Ct. s.*:-Secondary line of ctenia ; *Dent.*:-Denticle ; *Fib. l.*:- Fibrillary layer ; *Lab. nu.*:-Labyrinthiform nucleus ; *Lat. gr.*:-Groove caused by lateral line canal ; *Lat. rad.*:-Lateral radius ; *Nu.*:-Nucleus ; *Ost. pl.*:-Osteoid plate ; *Rad.*:-Radius ; *Sc. in.*:-Inset scale ; *Tub.*:-Tubercle.

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## A New Species of *Meliola* on *Butea monosperma* (Lam.) Kze.

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In December 1951, a few leaves of *Butea monosperma*, bearing a superficial sooty fungal growth were collected from Rajinderpur forests, Dacca Division, East Pakistan. The microscopic examination revealed that the fungus belonged to the genus *Meliola*. The literature on the subject showed that no species of this genus had so far been reported on *Butea monosperma* (Lam.) Kze. This was further confirmed by the staff of the Commonwealth Mycological Institute, Kew, England. For reasons stated above the fungus is considered to be an undescribed species of *Meliola*, and the name *M. buteae* is proposed for it.

***Meliola buteae*** n. sp.
(Figs 1,2).

*Plagulae* epiphyllae, orbiculares, atrae, numerosae et late confluentes. *Mycelium* ex hyphis atrobrunneis, 5. 7-7. 6. μ crassis. *Hyphopodia capitata* recta vel curvata, cellula apicali ovata vel globosa 3.8-7.6 x 7.6-15.2 μ (aver. 4.4 x 11.8 μ). *Setae myceliales* dispersae et juxte perithecia aggregatae, rectae vel irregulariter curvatae, 221-637 x 6.5 μ (aver. 297 x 6.5 μ). *Perithecia* dispersa, atra, globosa, 104-208 x 104-195 μ (aver. 135.7 x 143.8 μ). *Sporae* atrobrunneae, oblongae, utrinque rotundatae, constrictae 38-47.5 x 15.2-19 μ (43.2 x 16.7 μ).

*Colonies* epiphyllous, orbicular becoming confluent and covering almost entirely the greater part of the leaf. *Mycelium* formed of broad dark brown, septate, branched, 5.7-7.6 μ thick hyphae. *Hyphopodia* dark brown, 2-celled, straight or more or less curved; lower cell comparatively much smaller and cylindrical and the upper cell ovate or globose, 3.8-7.6 x 7.6-15.2 μ with on average of 4.4 x 11.8 μ. *Mycelial Setae* simple, septate; surrounding the perithecia, 221-637 x 6.5 μ with an average of 297.2 x 6.5μ. *Perithecia* globular, almost dark, 104-208 x 104-195 μ with an average of 135.7 x 143.8 μ. *Spores* dark brown to almost dark, oblong with rounded ends and slightly constricted at the septa, 38-47.5 x 15.2 x 19 μ with an average of 16.7 x 43.2 μ.

HABITAT : *Butea monosperma* (Lam.) Kze. (=*B. frondosa* Koenig) ; collected December. 1951.

LOCALITY : Rajinderpur forests, Dacca Division.

TYPE SPECIMEN : At Central Mycological Herbarium, Department of Plant Protection, Karachi (no. 2284) ; Co-types at Herbarium, Commonwealth Mycological Institute, Kew.

The authors are highly indebted to the Director, Commonwealth Mycological Institute, Kew, Surrey, England for confirming the identification.

Fig. 1. A leaf (left) and a leaflet (right) of *Butea monosperma* showing the general appearance of the sooty fungal growth.

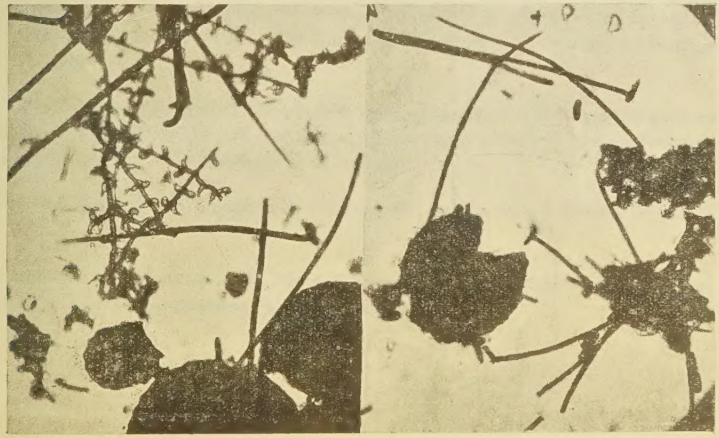

Fig. 2. Perithecia, mycelial setae, hyphopodia and spores, x 120.

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## *CONTENTS*


AHMAD, S., Pezizales of West Pakistan ... ... ... 1

AHMAD, M., A new termite from East Pakistan (Isoptera, Termitidae) ... ... ... ... 25

KHAN, M.A., & AHMAD, M., The imago of *Kalotermes beesoni* Gardner (Isoptera, Kalotermitidae) ... ... 28

AKHTAR, S.A., A new Spirurid (Nematoda : Acuariidae) from a Hornbill ... ... ... ... 31

SALEEM, M., Two new genera of hypermastigote flagellates from the termite *Archotermopsis wroughtoni* (Desneux) ... ... ... ... ... 34

ANSARI, M.A.R., The genus *Retortamonas* Grassi (Mastigophora : Retortamonidae) ... ... ... 40

FARIDI, M.A.F., A contribution to the Charales of West Pakistan ... ... ... ... ... 70

HAQUE, A.K.M.A., On the morphology of scales in some teleost fishes ... ... ... ... 82

HAFIZ, A., AZMATULLAH, & KAFI, A., A new species of *Meliola* on *Butea monosperma* (Lam.) Kze. ... ... 112


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Printed and published by Dr Sultan Ahmad at the Urdu Press, 88, McLeod Road, Lahore